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TITLE DYNAMIC ASSESSMENT OF B-52B-008 CARRIER AIRCRAFT FOR THE REVISED SPACE SHUTTLE SOLID ROCKET BOOSTER DECELERATOR SUBSYSTEM DROP TEST VEHICLE.

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(NASA-CR-170989) DYNAMIC ASSESSMENT OF B-52B-008 CARRIER AIRCRAFT FOR THE REVISED SPACE SHUTTLE SOLID ROCKET BOOSTER DECELERATOR SUBSYSTEM DROP TEST VEHICLE (Boeing Military Airplane Development) 53 p G3/16 N84-21606 Unclas 18615

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ABSTRACT

In order to reduce water impact damage to the shuttle booster rockets a larger main parachute for the recovery system was designed to slow the descent rate of the boosters. New tests were necessary to verify the structural integrity of the new parachute system. The Drop Test Vehicle was built for George C. Marshall Space Flight Center by Martin Marietta-Denver. Testing of the new parachute system is being done at the NASA Hugh L. Dryden Flight Research Facility and the Naval Weapons Center China Lake facility.

The purpose of this study was to determine by theoretical analysis the structural integrity of B-52B-008, pylon, and hooks for the drop test missions. The results of the analysis and conclusions are presented in this document.

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1. INTRODUCTION

This contract for study and testing is an outgrowth of an earlier NASA Contract in effect from 1976 to 1978 when B-52B-008 was used as a Drop Test Vehicle (DTV) to test the Solid Rocket Booster (SRB) parachute system. The results of the first analyses are documented in References 1, 2, 3, 4, 5, 6, 7, and 8. The new parachute system includes a larger main parachute which will lower the descent rate of the SRB. The major modification to the DTV was shortening it about 54 inches, which resulted in the forward hook attach structure being located at the base of the nose cone. The shims that are located in the aft hook structures are increased from two inches to three inches. A sketch of B-52B-008 with the DTV mounted under its wing is shown in Figure 1. A sketch of the shortened DTV is shown in Figure 2.

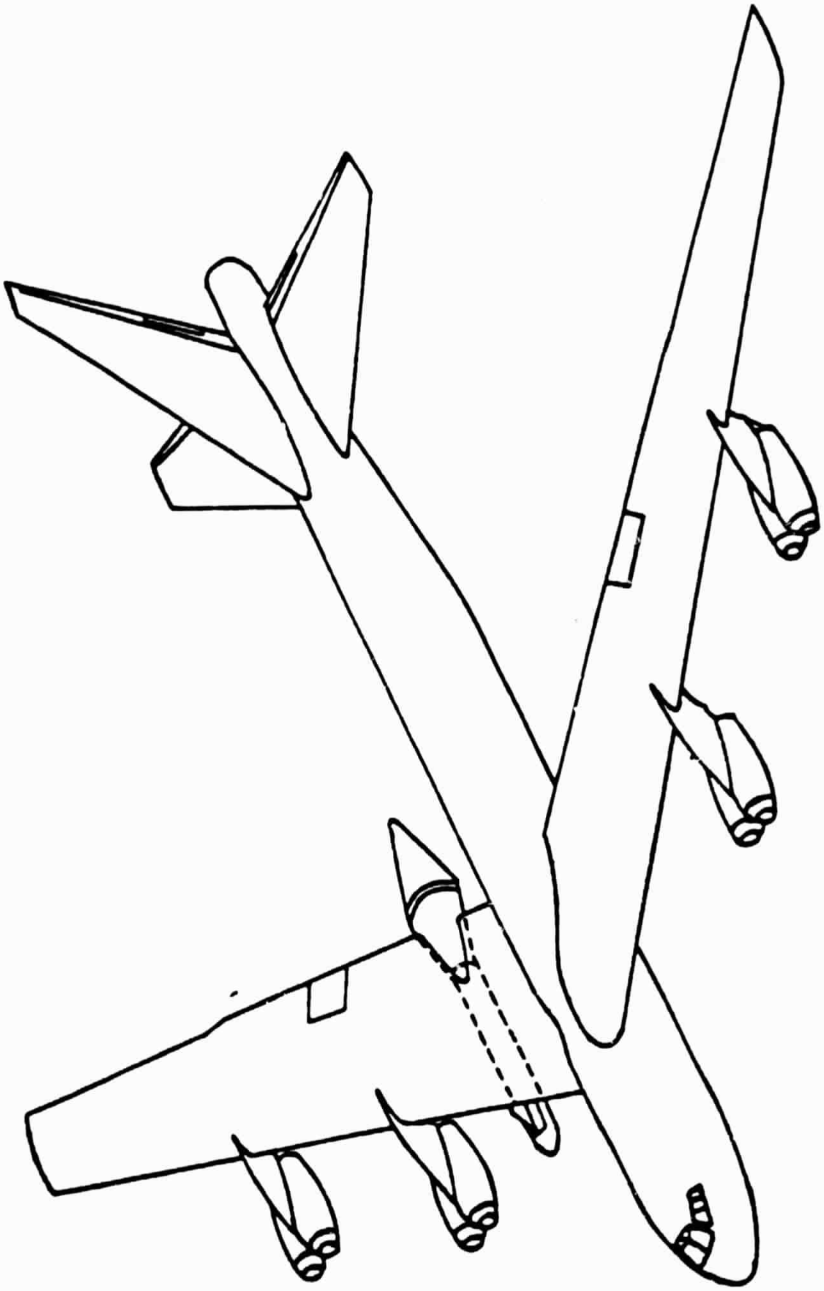


FIGURE 1
B-52B-008/DTV CONFIGURATION DESCRIPTION

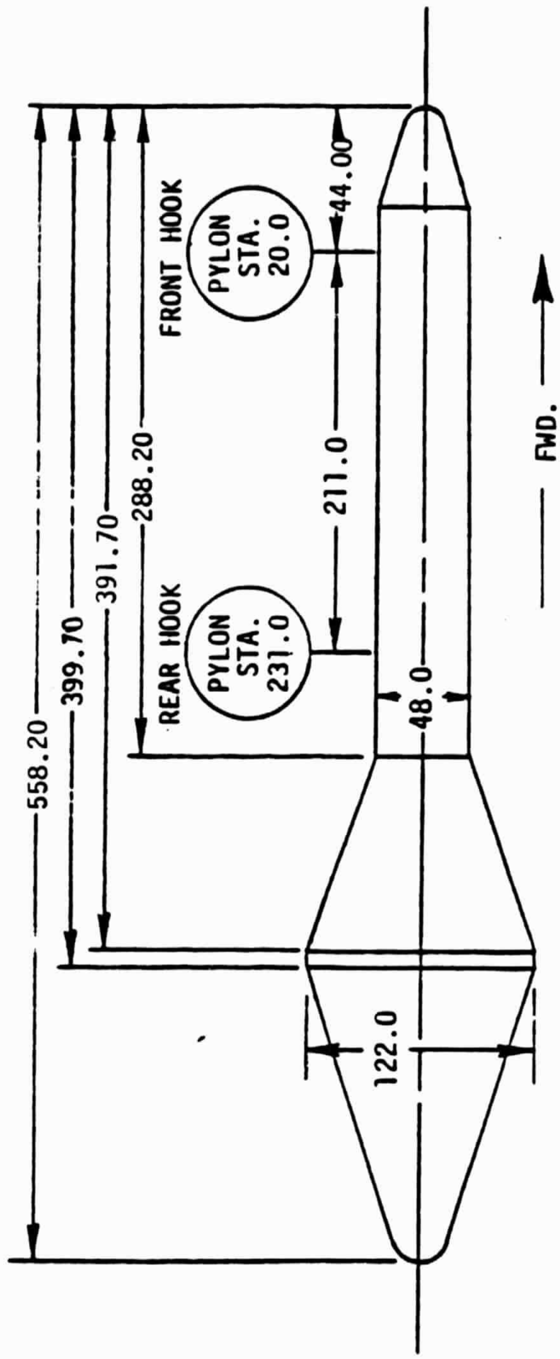


FIGURE 2

DTV CONFIGURATION DEFINITION

2. SUMMARY

This document presents further study of the DTV for the new parachute system to recover the SRB's. This study is similar to the study made in 1976 and 1977 except for the following differences:

1. The parachute system has been modified.

2. The DTV has been shortened by 54 inches and the aft shim on the two aft hooks has been increased to three inches.

3. The forward hook attach location is at the base of nose cone.

The purpose of the study is to verify the B-52B-008/DTV compatibility and B-52B-008 pylon structural capability to accomplish the drop test mission for testing the improved parachute system. The new dimensions of the DTV are given in Figure 2. The fuel sequence remains unchanged as stated in the References 1 and 4. While the airspeed restriction of 300 knots calibrated or Mach .75 is satisfactory to assure flutter-free flight, the greater restriction of 260 knots calibrated or Mach .75 (whichever is less) is necessary to assure no structural negative margins of the attach structure of the DTV to the pylon.

Pylon structural evaluation results were compared with the X-15A-2 load factor criteria and the previous analyses results. The analyses show that the pylon is acceptable for the shorter DTV and increasing the aft shims to three inches.

Based on the results of flutter and dynamic loads analyses, recommendations are as follows:

- o Fly only when the forecasted turbulence in the test area is none or light.
- o Avoid abrupt elevator, aileron, and rudder inputs.
- o Minimize landing impact speed when landing with the DTV still attached to the pylon.

3. FUEL SEQUENCE

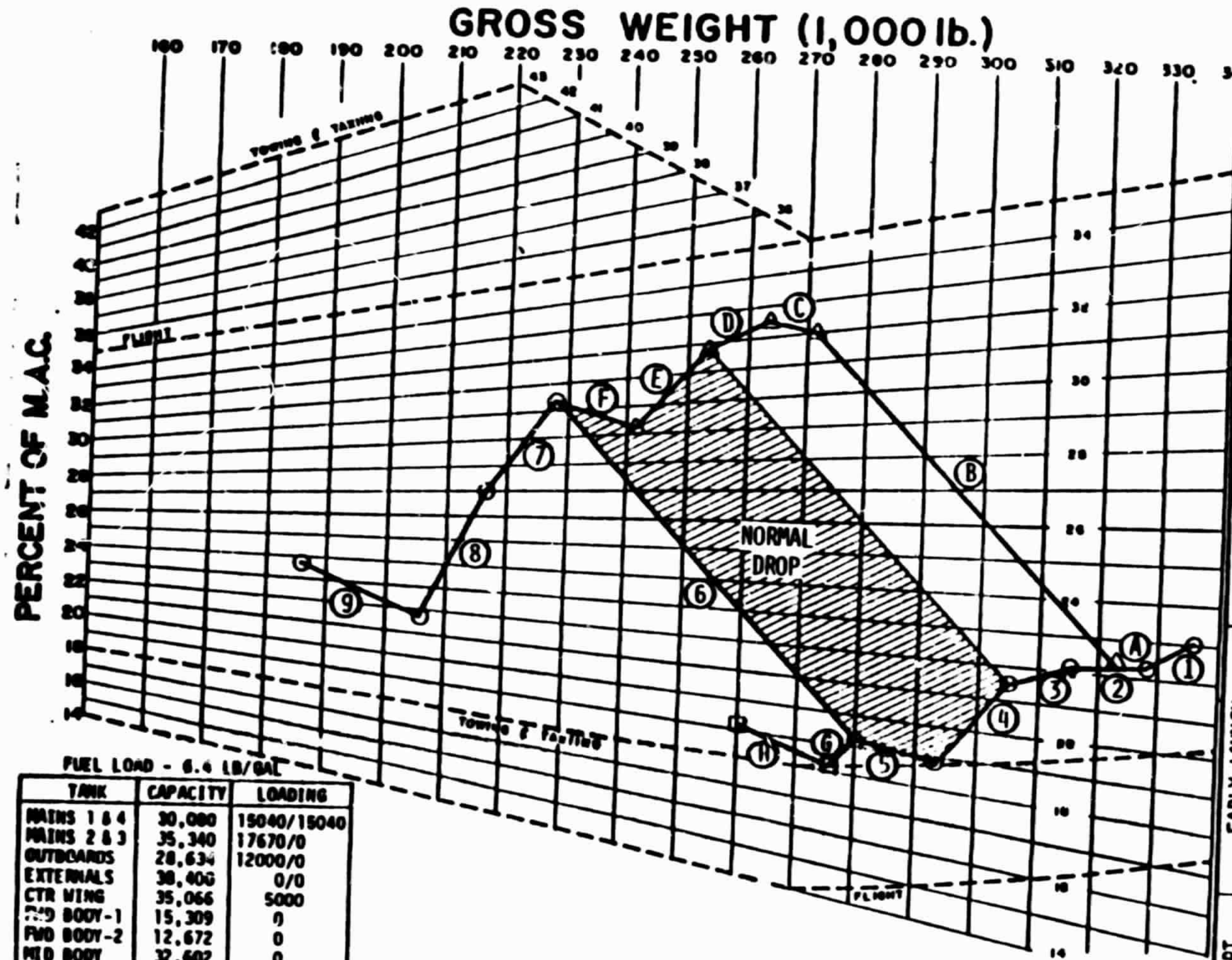
All the fuel sequence requirements remain unchanged from those given in Reference 1. The fuel sequence grids are reproduced for this report and are given in Figures 3 and 4. The paragraph on fuel sequence is copied below from Reference 5. Based on the NASA mission requirement that the B-52B have a maximum fuel capability of 100,000 pounds, a fuel sequence was developed which minimizes aircraft structural loading and flutter degradation. The fuel sequence was developed using the following criteria:

- o Airplane rolling moment is balanced by left hand wing fuel for takeoff.
- o Gradual airplane rolling moment unbalance is obtained by fuel burn and transfer from the left hand wing. At the time of DTV drop, the airplane rolling moment unbalance will be approximately one-half of the unbalance caused by the DTV.
- o After DTV drop, the airplane will be approximately rebalanced by fuel burn and fuel transfer for landing.

Based on these criteria and the mission requirement, the maximum B-52B/DTV weight was established as 336,344 pounds. The weight was allocated as follows:

o	B-52B-008 (including LOX Tank) + Pylon + Crew	= 181,344 Pounds
o	Maximum DTV weight	= 52,000 Pounds
o	Water Injection - H_2O	= 3,000 Pounds
o	Maximum Fuel Weight	= 100,000 Pounds
o	LOX	= 0 Pounds

Early DTV drop (emergency drop), normal DTV drop and mission abort fuel sequencing procedures are defined in Figures 3 and 4. The fuel sequence as developed maintains good longitudinal and lateral CG control during all phases of operation. The fuel sequence as presented is based on 6.4 pound per gallon density fuel.



FUEL LOAD - 6.4 LB/GAL

TANK	CAPACITY	LOADING
MAINS 1 & 4	30,080	15040/15040
MAINS 2 & 3	35,340	17670/0
OUTBOARDS	28,634	12000/0
EXTERNALS	38,406	0/0
CTR WING	35,066	5000
FWD BODY-1	15,309	0
FWD BODY-2	12,672	0
MID BODY	32,602	0
AFT BODY	37,837	35250
TOTAL FUEL	265,940	100000

LEGEND

	SYM	TANK	FUEL IN POUNDS USED	FUEL IN POUNDS REMAINING
NORMAL LAUNCH	1	MAIN 1 MAIN 2 MAIN 4 WATER	1203 2406 1203 3000	13837 15264 13837 0
	2	L. OUTBD MAIN 2	6500 6500	5500 8764
	3	AFT BODY CTR WING	5000 5000	30250 0
	4	AFT BODY MAIN 2	9000 3000	21250 5764
	5	MAIN 1 MAIN 4	6837 6837	7000 7000
	6	LAUNCH	52000	0
	7	L. OUTBD AFT BODY	5500 5500	0 15750
	8	AFT BODY	10750	5000
	9	MAIN 1 MAIN 2 MAIN 4	7000 5764 7000	0 0 0
EARLY LAUNCH	A	L. OUTBD MAIN 2	2500 2500	9500 12764
	B	LAUNCH	52000	0
	C	L. OUTBD MAIN 2	4000 4000	5500 8764
	D	AFT BODY CTR WING	5000 5000	30250 0
	E	AFT BODY MAIN 2	9000 3000	21250 5764
	F	MAIN 1 MAIN 4	6837 6837	7000 7000
ABORT	G	MAIN 1 MAIN 4 AFT BODY L. OUTBD	2000 2000 -8817 +8817	5000 5000 12433 14317
	H	MAIN 1 MAIN 2 MAIN 4	5000 5764 5000	0 0 0

FIGURE 3

FUEL SEQUENCE GRID (LONGITUDINAL CG)

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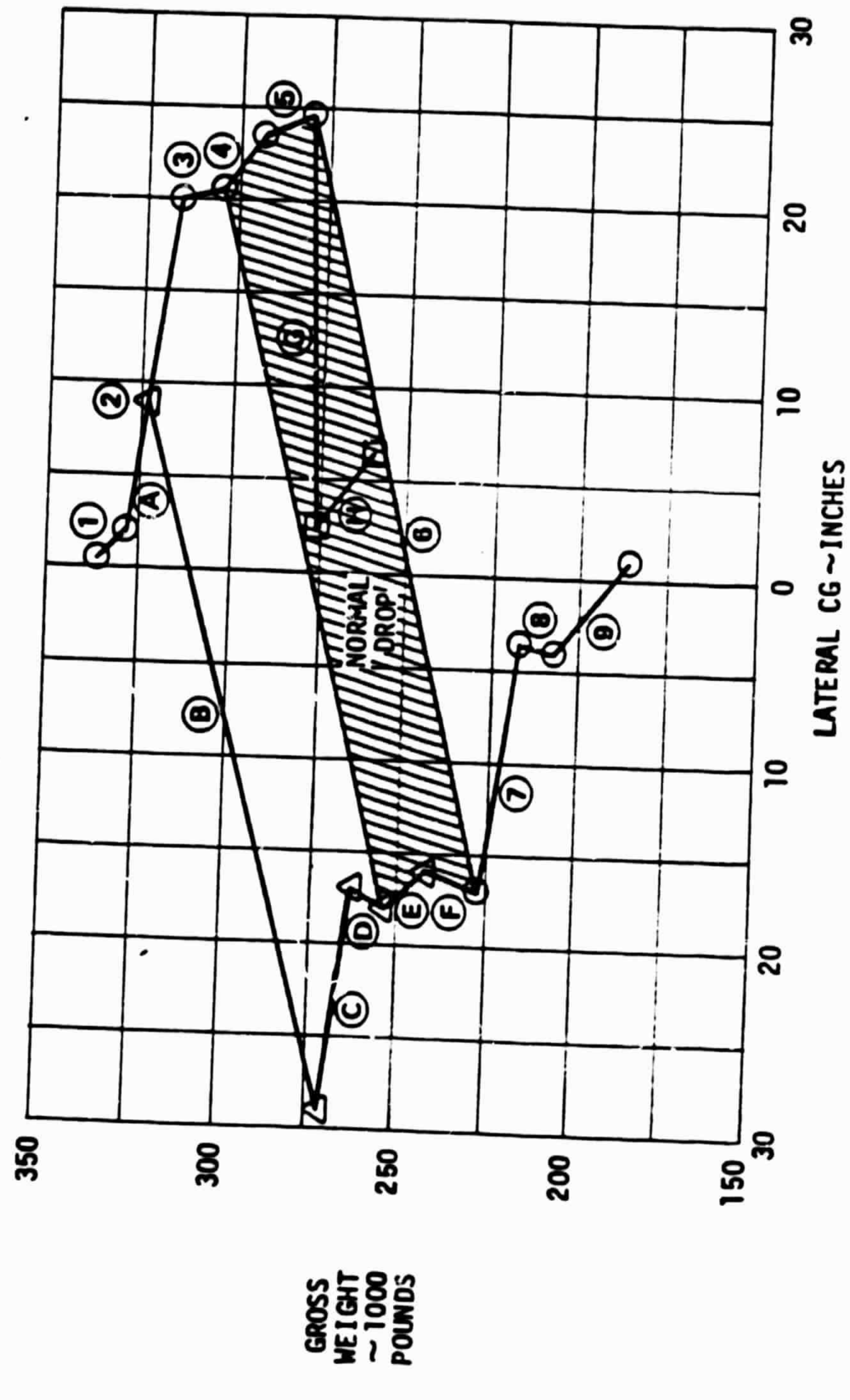


FIGURE 4
FUEL SEQUENCE GRID (LATERAL CG)

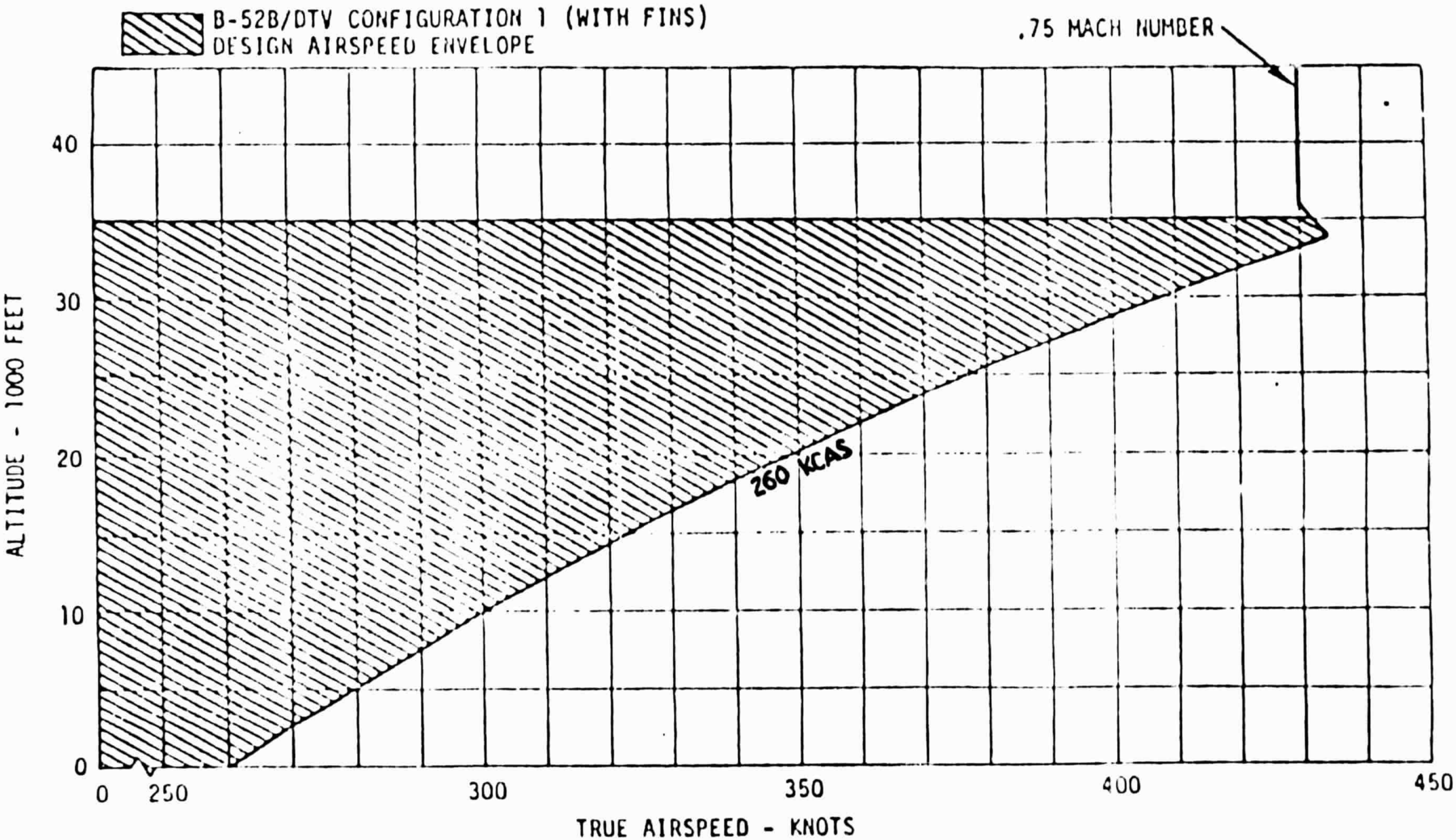
4. FLUTTER

Because the DTV had been shortened, flutter analyses were performed to verify the airplane is flutter free within the design envelope as shown in Figure 5. The airplane is cleared to 15 percent above the equivalent design airspeed for a margin of safety.

4.1 Method of Analysis. Unsymmetric flutter analyses were conducted to allow for different left and right hand wing fuel loadings and for carriage of the DTV Configuration at the right hand pylon location. Coupled airplane vibration analyses were based on an elastic axis lumped parameter representation of the airplane as shown in Figure 6. Vibration modes for the DTV/pylon configuration were determined based on X-15 ground vibration test results. Cantilever vibration frequencies for DTV Configuration are shown in Figure 7. Unsteady aerodynamic forces for the airplane were generated based on lifting surface theory which used the patch paneling as shown in Figure 8. The flutter equations are discussed in Reference 6, Section 2.2 on pages 16 through 19 and are still the basis for the analyses for study in this contractural agreement.

Flutter analyses were accomplished at two altitudes of 21,000 and 33,000 feet for .75 and .86 Mach numbers. Two gross weight conditions (approximately 316,000 pounds and 273,000 pounds) on the fuel sequence defined in Figures 3 and 4 were selected based on flutter criticality as experienced during past flutter testing and analysis results of other B-52 programs. The 315,000 pound condition (main 1 and 4 at 92 percent, main 2 at 59 percent and left outboard at 50 percent) is on the normal launch sequence whereas the 273,000 pound condition (mains 1, 2 and 4 at 33 percent and left outboard full) is for an aborted mission.

4.2 Analysis Results. Summary results are presented in this section for both the weight conditions. The weight conditions are given in Figure 9. The flutter analyses were conducted at 33,000 feet and 21,000 feet. At 33,000 feet altitude the design velocity (V_D) and 1.15 V_D airspeeds are 436 and 501 knots true airspeed, respectively. At 21000 feet altitude the VD and 1.15 VD airspeeds are 406 and 467 knots true airspeed, respectively. Structural damping is not included in the flutter analyses. A value of .015 for structural damping is considered a minimum which means all flutter analyses are conservative by at least .015 as given in Figures 10 through 15. Again the heavy gross weight is more unstable than the lighter airplane. However, the airplane is stable within the design envelope and the 15 percent margin of safety.



B-52B/DTV CONFIGURATION 1 (WITH FINS)
DESIGN AIRSPEED ENVELOPE

FIGURE 5

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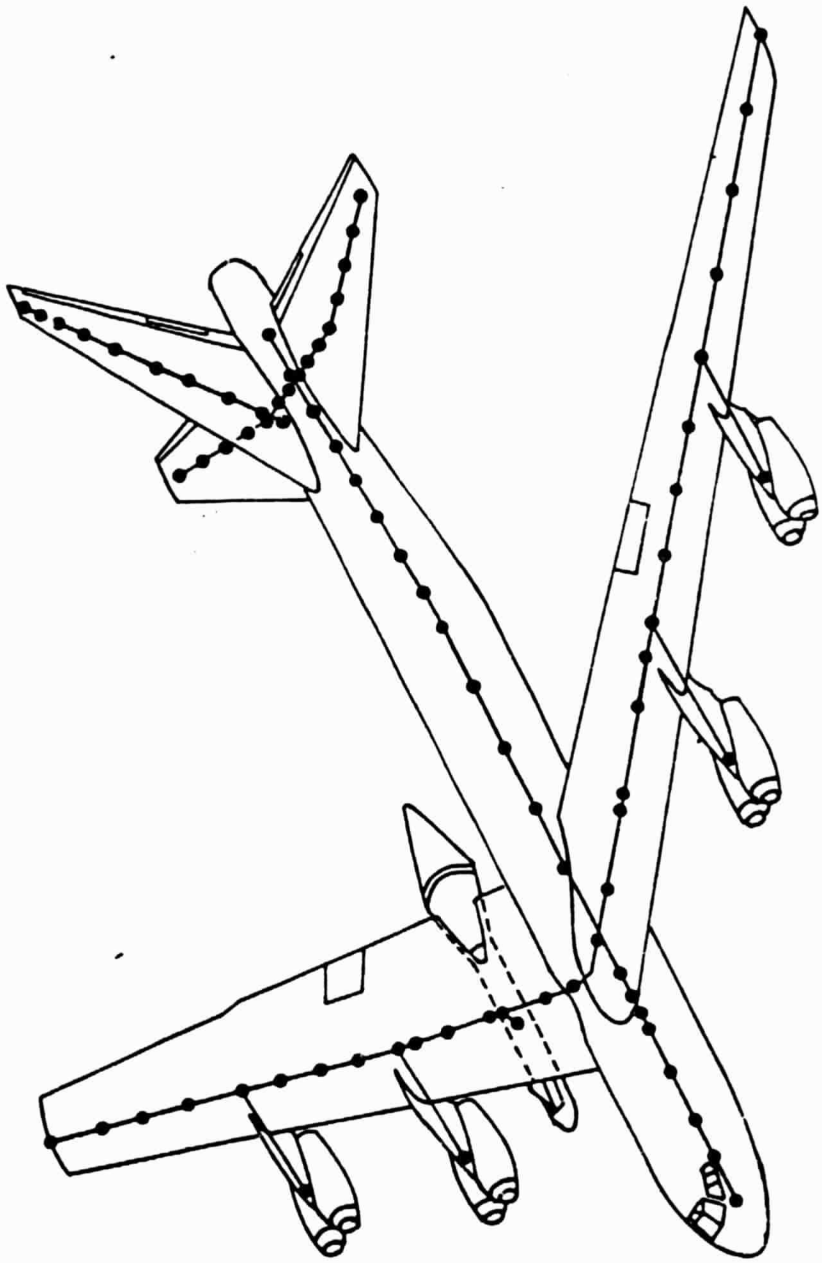

FIGURE 6
ELASTIC AXIS REPRESENTATION
B-52B/DTV CONFIGURATION

CONFIGURATION / MODE	X-15 + PYLON (1)	PREVIOUS DTV + PYLON (2)	NEW DTV + PYLON (3)
LATERAL (F1) (4)	4.29 HZ	1.89 HZ	2.08 HZ
LATERAL (F2) (5)	4.75 HZ	2.52 HZ	2.53 HZ
PITCH (F3) (6)	5.34 HZ	2.34 HZ	2.62 HZ

1. X-15 Inertia Properties; Weight = 12636 Pounds, I_{PITCH} = 75151 Slug-Ft^2, I_{YAW} = 76620 Slug-Ft^2, I_{ROLL} = 3373 Slug-Ft^2, Reference D3-1652, Page 7
   X-15 + Pylon Frequency Data obtained from D3-2121, Page 2.
2. Previous DTV Inertia Properties; Weight = 48500 Pounds, I_{PITCH} = 399100 Slug-Ft^2, I_{YAW} = 399100 Slug-Ft^2, I_{ROLL} = 6830 Slug-Ft^2
3. Inertia Properties; Weight = 49000 Pounds, I_{PITCH} = 315000 Slug-Ft^2, I_{YAW} = 315000 Slug-Ft^2, I_{ROLL} = 9831 Slug-Ft^2
4. Primarily a DTV - Pylon yaw (torsion) mode with some side bending
5. Primarily a DTV - Pylon side bending mode with some yaw (torsion)
6. A DTV - Pylon pitch mode

FIGURE 7

DTV-PYLON CANTILEVER FREQUENCIES

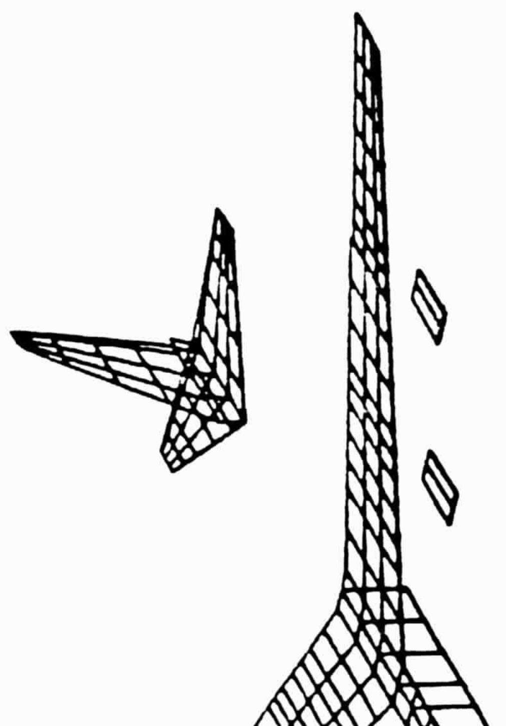

FIGURE 8
AERODYNAMIC PATCH PANELING
B-52B/DTV

OWE * (LBS)	DTV (LBS)	FUEL LOADINGS										WATER (LBS)	TOTAL AIRPLANE WEIGHT (LBS)
		LEFT OUTBD. (LBS)	MAIN 1 (LBS)	MAIN 2 (LBS)	CENTER WING (LBS)	MAIN 3 (LBS) **	MAIN 4 (LBS)	RIGHT OUTBD. (LBS)	FWD BODY (LBS)	MID BODY (LBS)	AFT BODY (LBS)		
181344	49000	7160	13837	10436	5000	---	13837	0	0	0	35250	0	315864
181344	49000	14317	5000	5776	0	---	5000	0	0	0	12433	0	272870

* OWE - Operating Weight Empty (Includes Pylon & Crew)

** Main Fuel Cell No. 3 has been removed from B-52B-008

FIGURE 9
FUEL LOADING

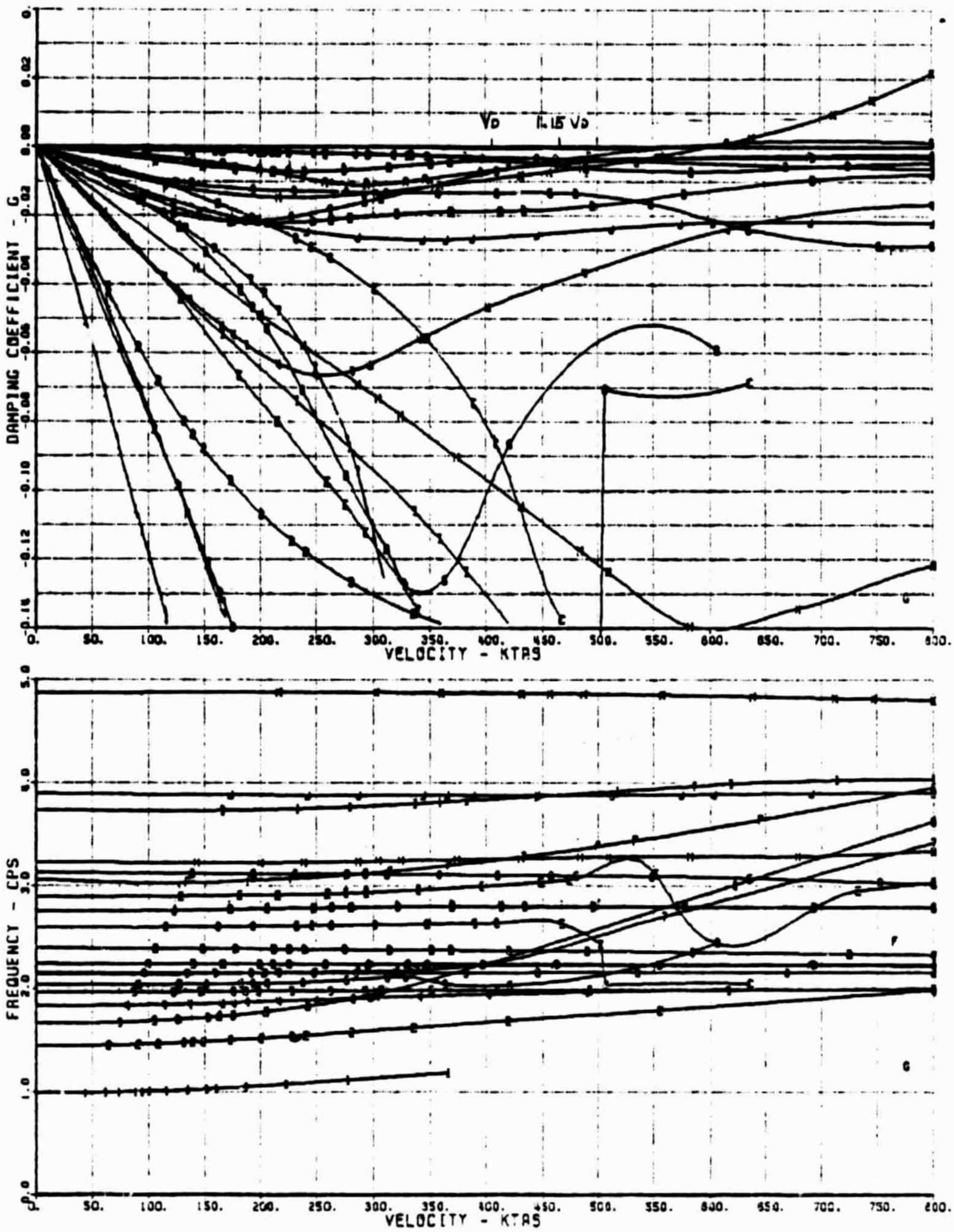

FIGURE 10

B-52B 315K 21000 FT M=.75 NEW CONF

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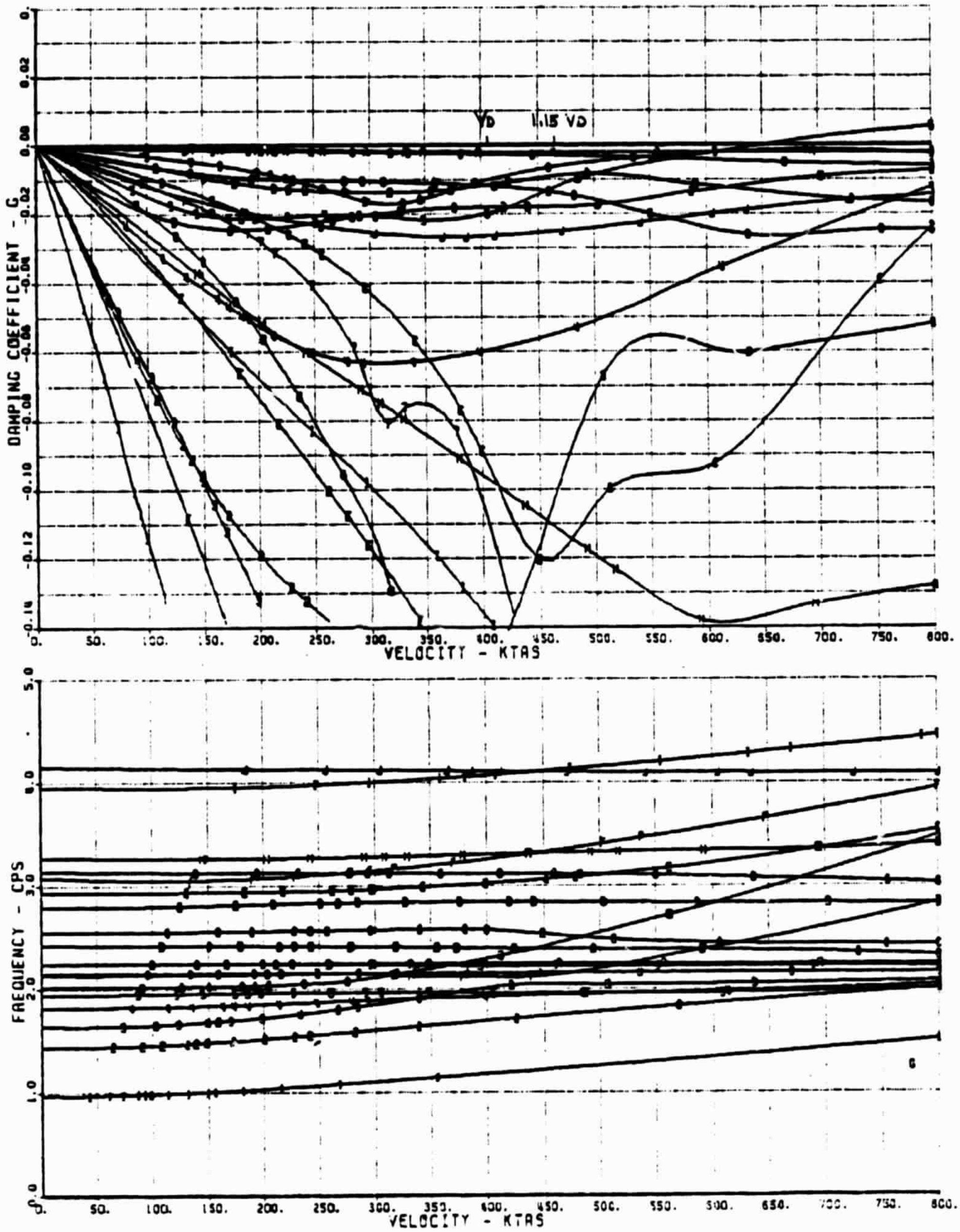


FIGURE 11

B-52B 273K 21000 FT M=.75 NEW CONF

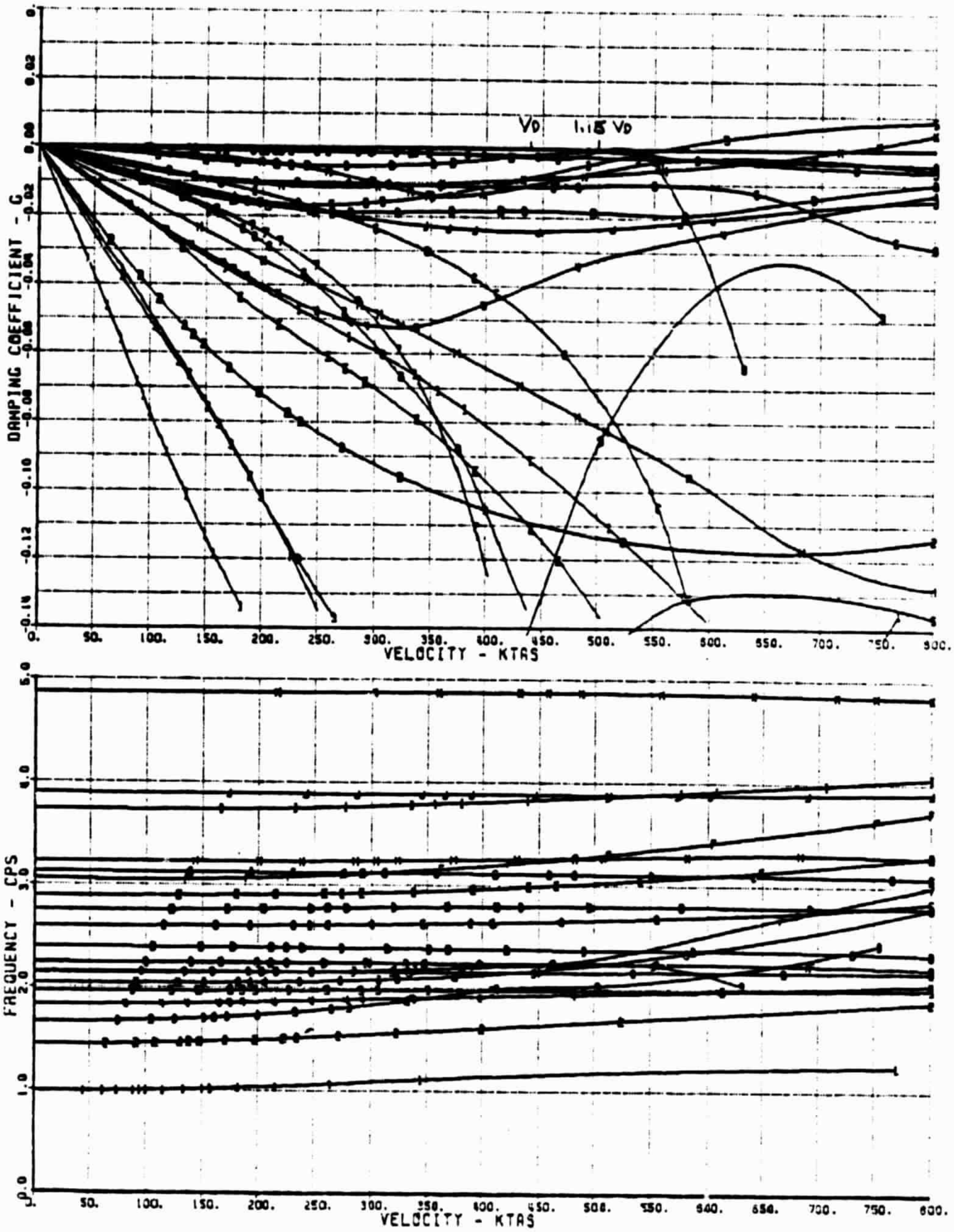


FIGURE 12

B-52B 315K 33000 FT M=.75 NEW CONF

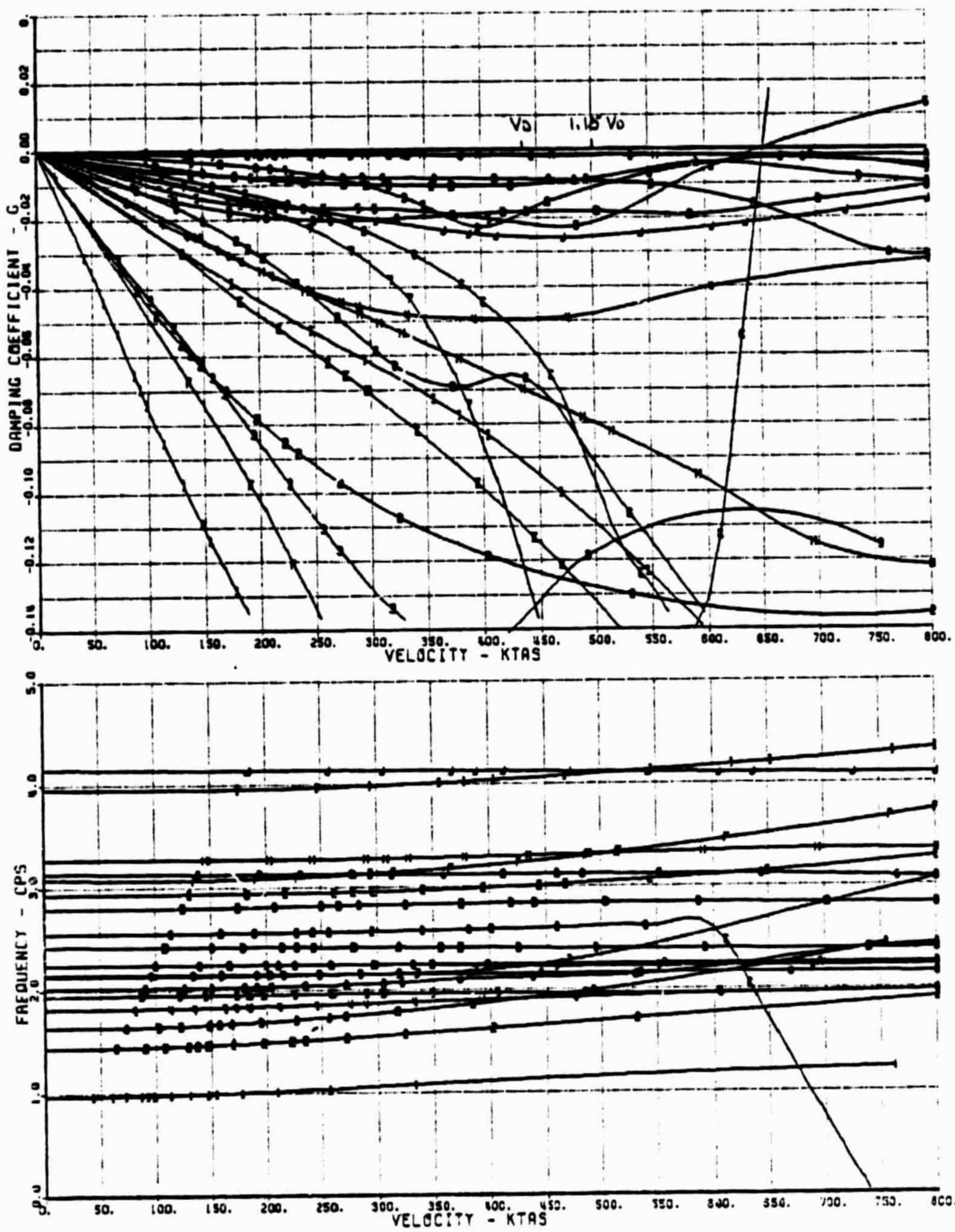


FIGURE 13

B-52B 273K 33000 FT M=.75 NEW CONF

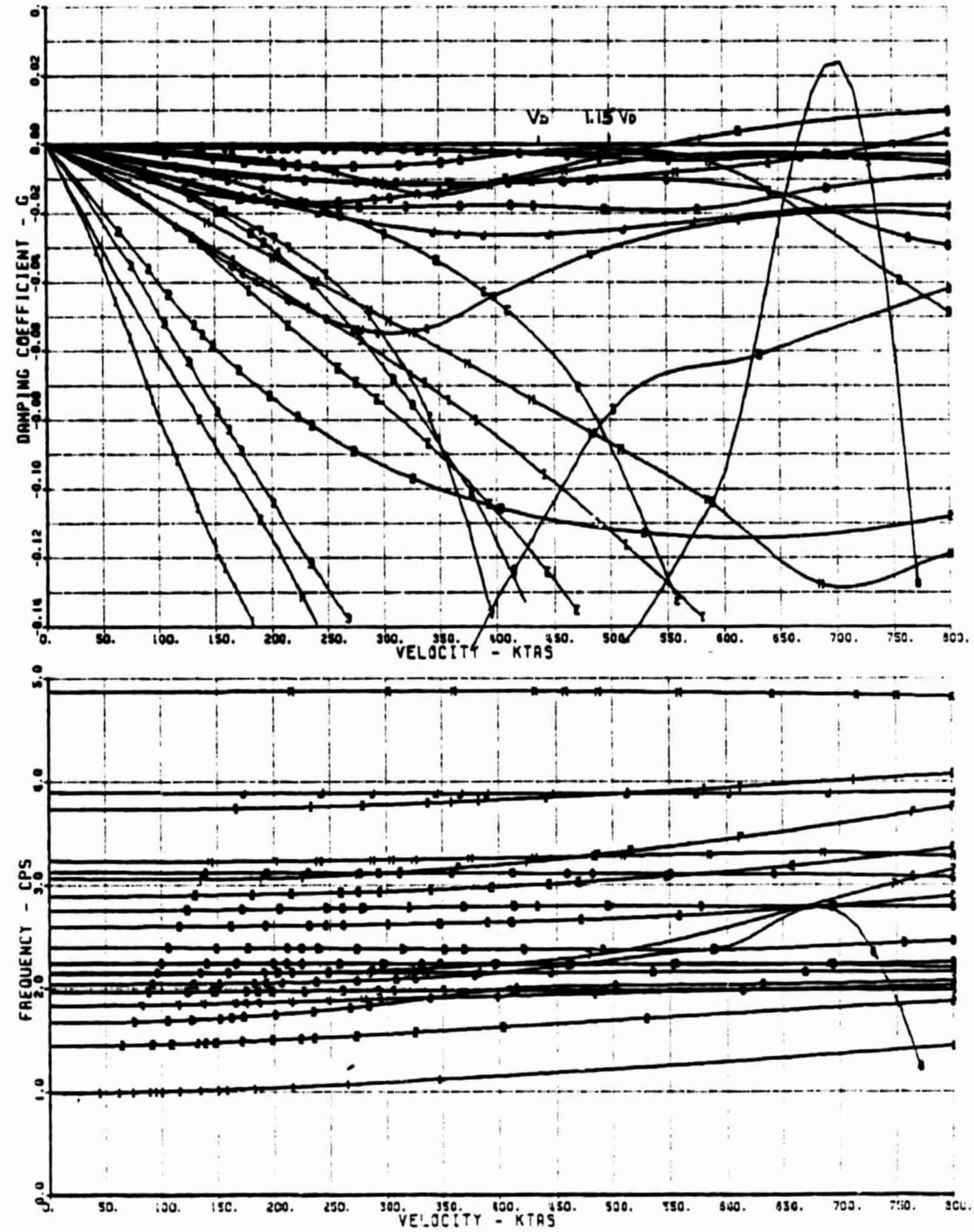
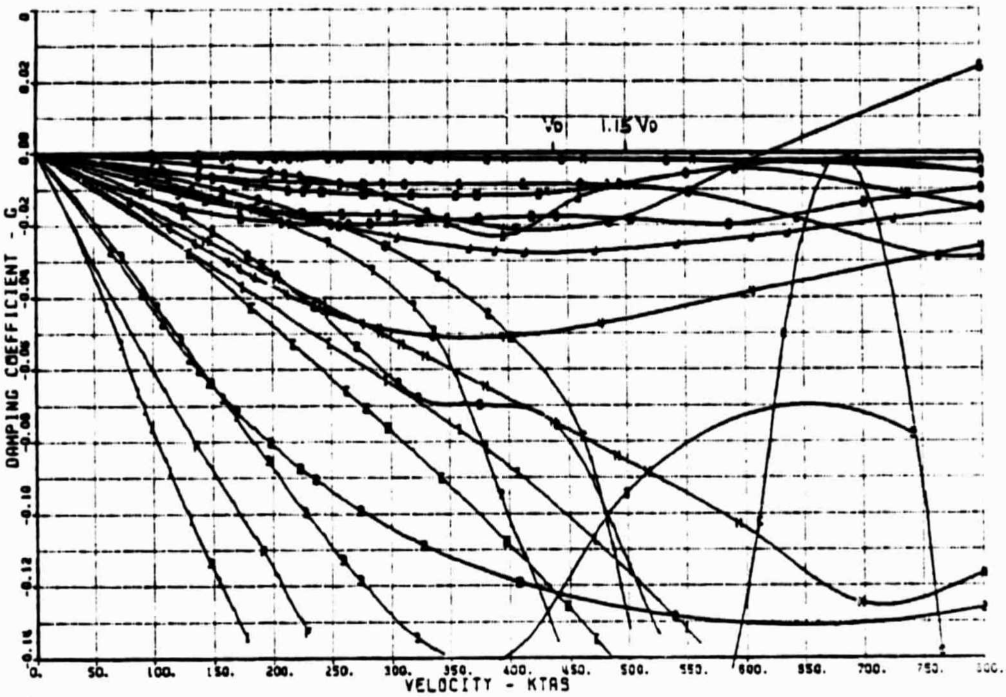


FIGURE 14

B-52B 315K 33000 FT M=.86 NEW CONF



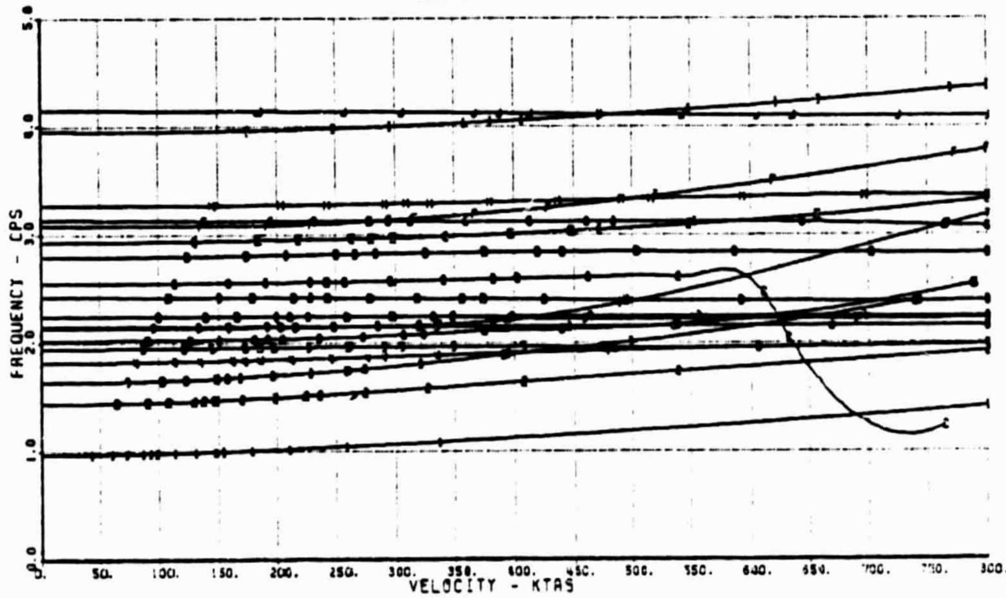


FIGURE 15

B-52B 273K 33000 FT M=.86 NEW CONF

5. AIRPLANE LOADS ANALYSIS

Loads analysis was accomplished using the design criteria stated in Reference 1. The limit load factors are given in Figure 16. The design criteria is restated again below as follows:

- o Maximum B-52B/DTV gross weight is 336,344 pounds.
- o Airspeed limitation is bounded by 260 KCAS and Mach .75, whichever is less.
- o Maximum flight altitude is 35,000 feet.
- o Maneuver flight loads factor restrictions are:
  - Positive limit load factor of 1.8 g's for weights in excess of 306000 pounds and 2.0 g's for weights at or below 306000 pounds.
  - Negative limit load factor of -.67 g's for all gross weights.
- o Gust load factors are given in Reference 9, page 7.
- o Landing loads - ultimate loads per gear are given in reference 10 page 2D-7.
- o Ultimate loads are 1.5 times limit loads. The fuel sequence remains the same as in previous analysis as given in Section 3 of Reference 1.

The major differences between the previous analyses in 1977 and the analyses performed this year are as follows: 1) The DTV has been shortened about 54 inches, and 2) the aft support shims increased to three inches.

5.1 Method of Analysis. The B-52B/DTV configuration was analyzed as an unsymmetric structure. The left and right wings had different fuel loadings caused by the location of the DTV on the right wing. The coupled airplane vibration model and unsteady aerodynamic forces are described in Section 4.1. Twenty-six coupled modes including four rigid-body modes were used to represent the B-52B/DTV configuration. Two rigid body modes (X- and Y- translation modes) were excluded because of the very small influence the two modes would have on the symmetrical loadings on the aircraft.

5.2 Analysis Results. Dynamic analyses of vertical gust, elevator maneuvers, and landing loads were performed to predict loads on pylon attach structures. The B-52 DTV was analyzed for a "1-cosine" vertical gust at 25 feet per second (true airspeed) at two altitudes (2000 feet and 33000 feet). The periods for the gust ranged from 0.2 to 4.0 seconds in duration. The maximum load for each time period is plotted against frequency of each period as shown Figures 17 through 23. The time periods for one elevator induced maneuver varied for 0.222 seconds to four seconds in duration. The maximum load for each time period is plotted against the frequency of each period as shown in Figures 24 through 30. The four landing conditions analyzed are as follows:

1. Simultaneous touchdown at three feet per second sink rate.

2. Three degrees nose up at three feet per second sink rate.

3. Six degrees nose up at three feet per second sink rate.

4. Three degrees nose up at six feet per second sink rate.

The load versus sink rates for each condition are given in Figures 31 through 37. The maximum loads for gust, elevator maneuver, and landing conditions are given in Figure 38. The twenty-five foot per second vertical gust gives the highest loads on the attach structures between the pylon and DTV. All loads are within the allowable margin of safety.

If the airplane is constrained by 260 knots calibrated airspeed and Mach .75 curves as given in Figure 39 the pylon is predicted to be of sufficient strength to withstand the loading calculated in the analyses. However, the maximum elevator deflection should be limited to five degrees when the maximum allowed airspeed is limited to 260 knots calibrated airspeed or Mach .75, whichever is less. The predicted loads are compared to the results of the minimal strength analyses of the X-15 vehicle in Figure 38. All loads on pylon attach structures have positive margins of safety.

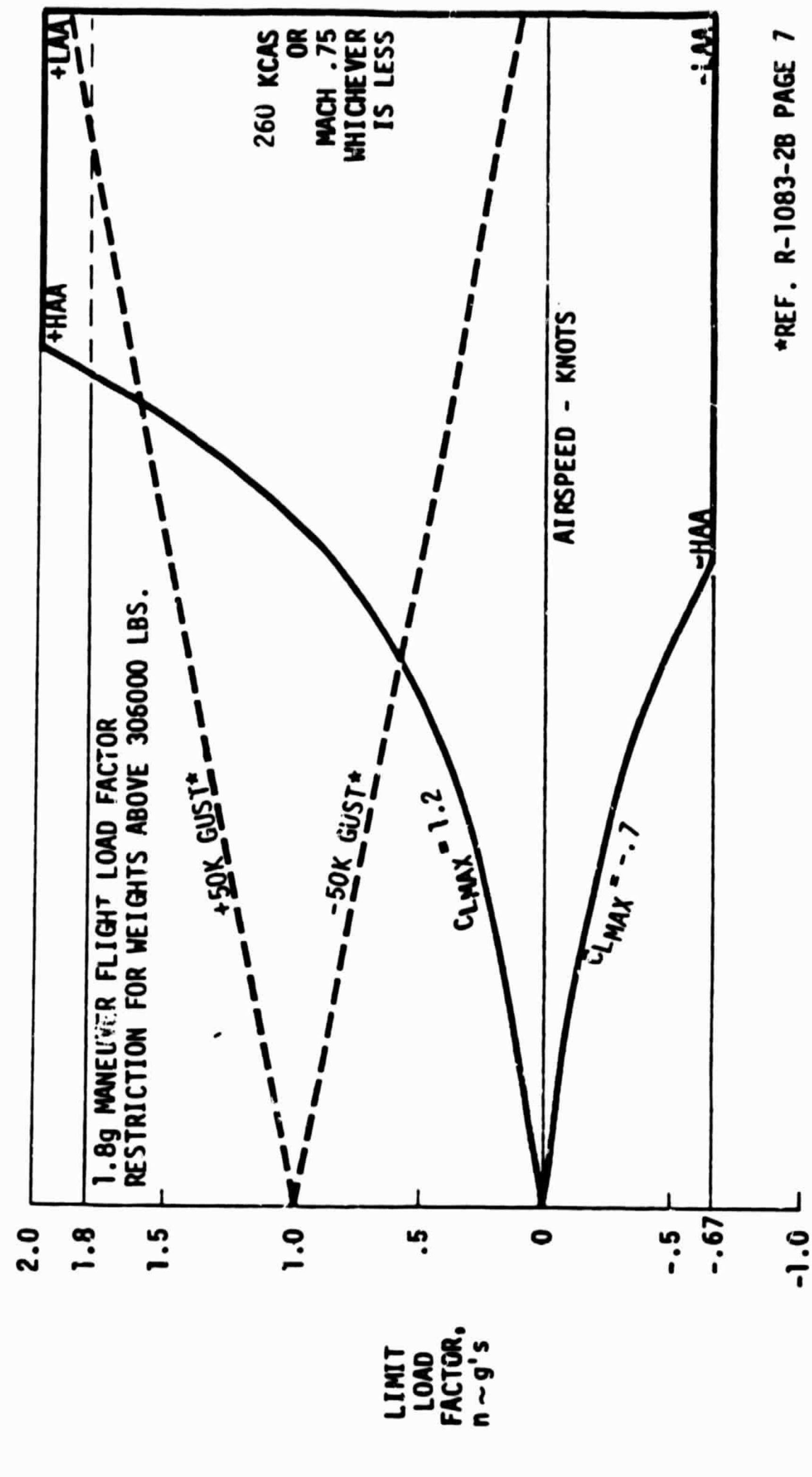


FIGURE 16
V-n DIAGRAM

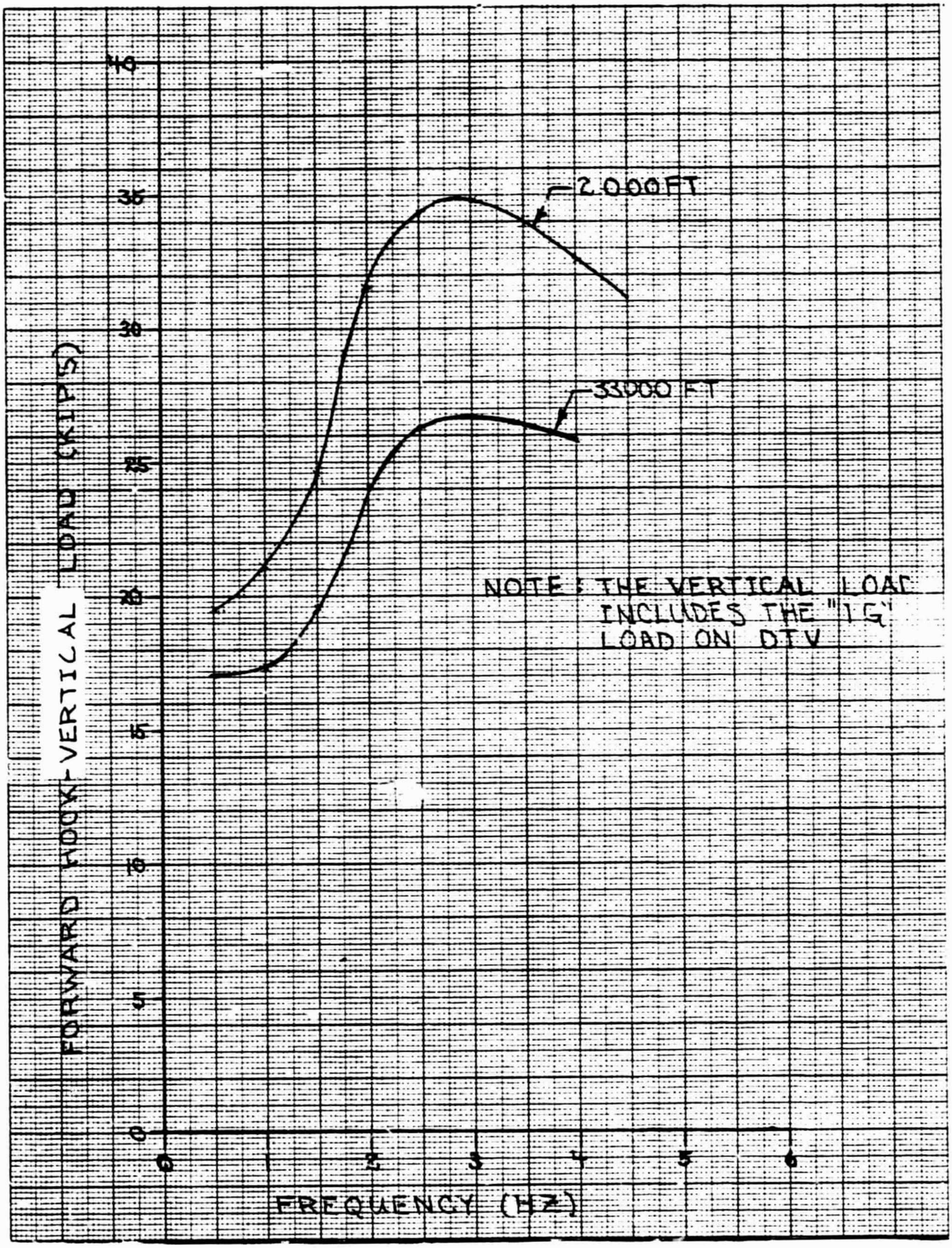


FIGURE 17

LOADS FOR ONE 25 FT/SEC GUST TRUE AIRSPEED AT THE ABOVE FREQUENCIES

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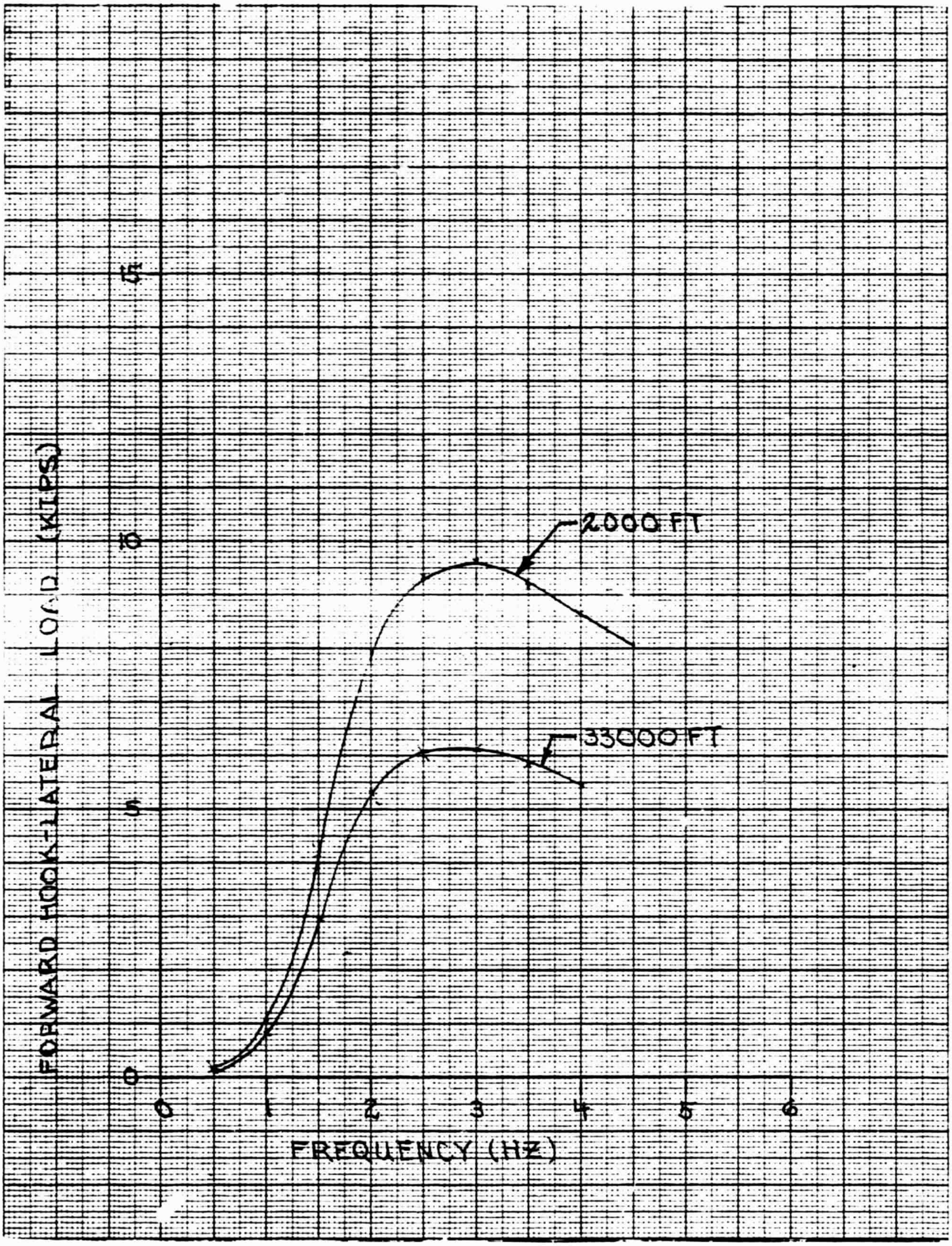

FIGURE 18

LOADS FOR ONE 25 FT/SEC GUST TRUE AIRSPEED AT THE ABOVE FREQUENCIES

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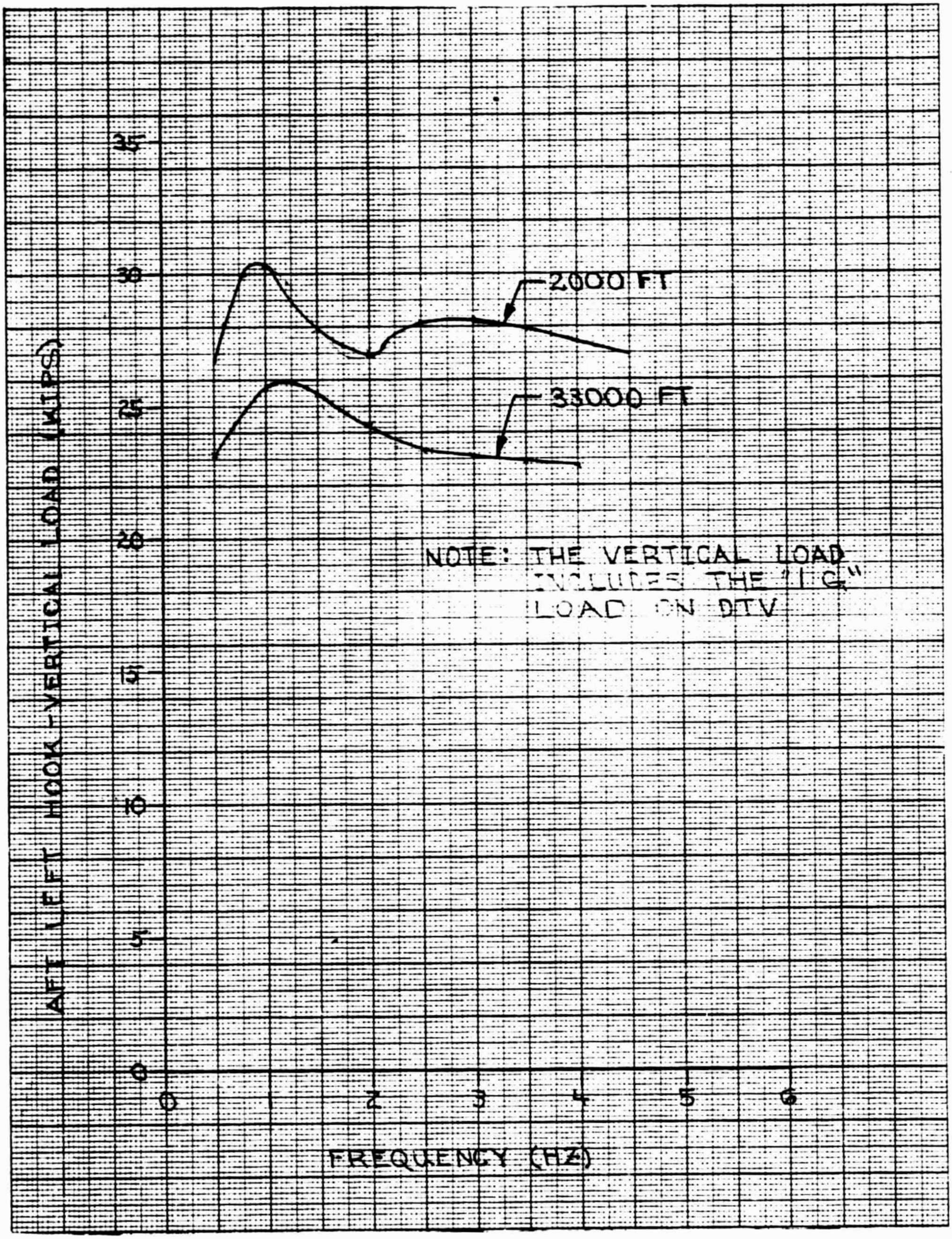

FIGURE 19

LOADS FOR ONE 25 FT/SEC GUST TRUE AIRSPEED AT THE ABOVE FREQUENCIES

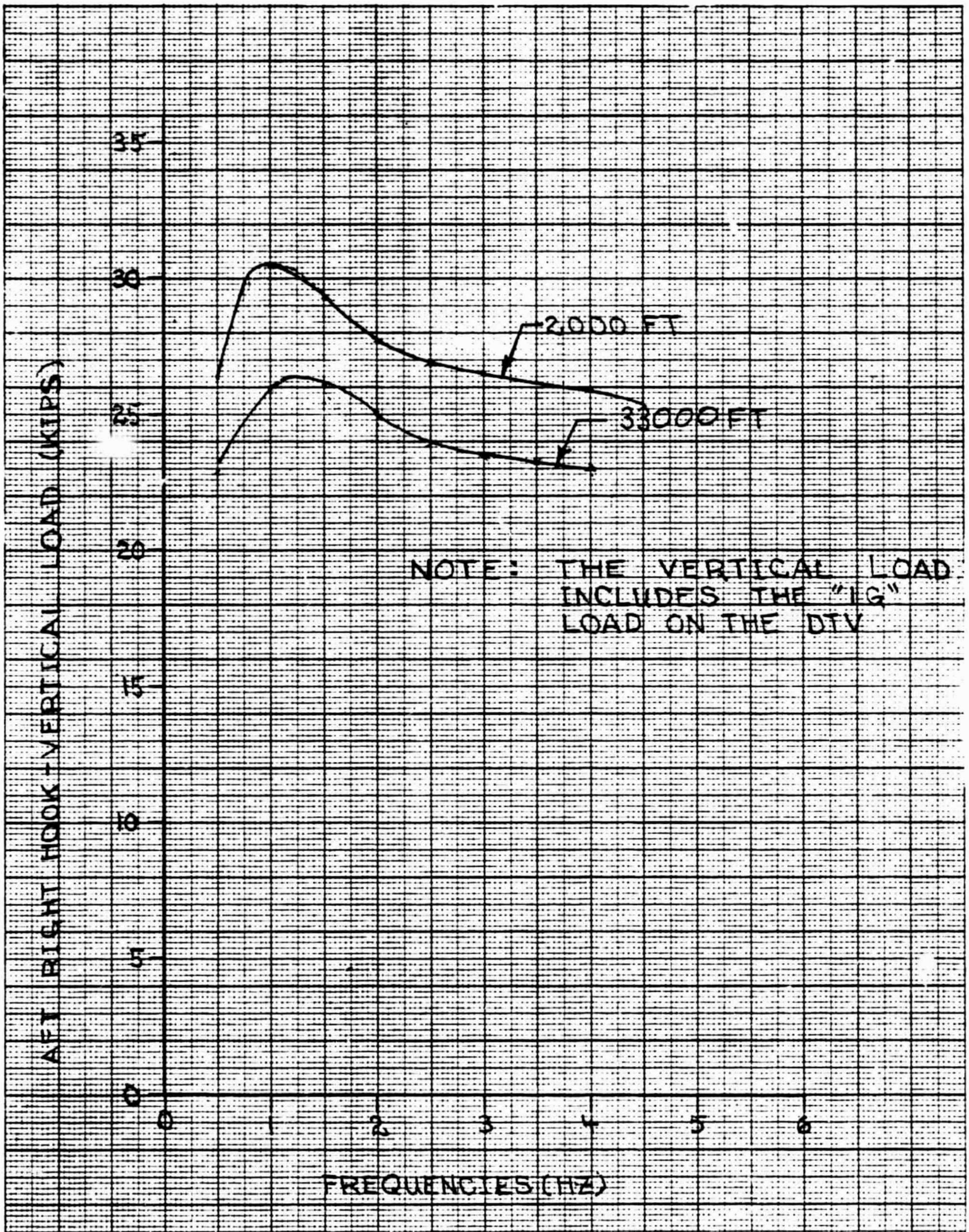

FIGURE 20

LOADS FOR ONE 25 FT/SEC GUST TRUE AIRSPEED AT THE ABOVE FREQUENCIES

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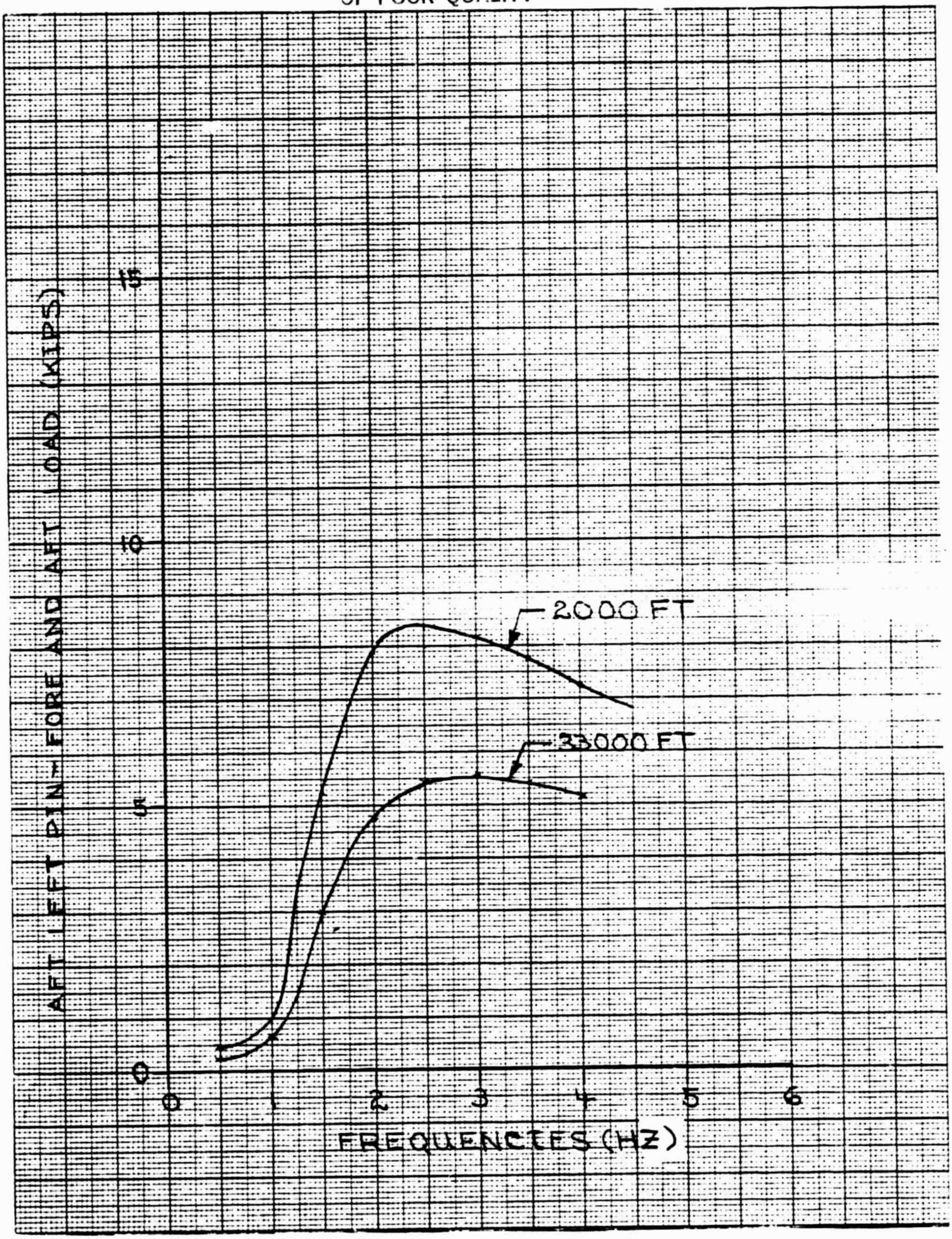

FIGURE 21
LOADS FOR ONE 25 FT/SEC GUST TRUE AIRSPEED AT THE ABOVE FREQUENCIES
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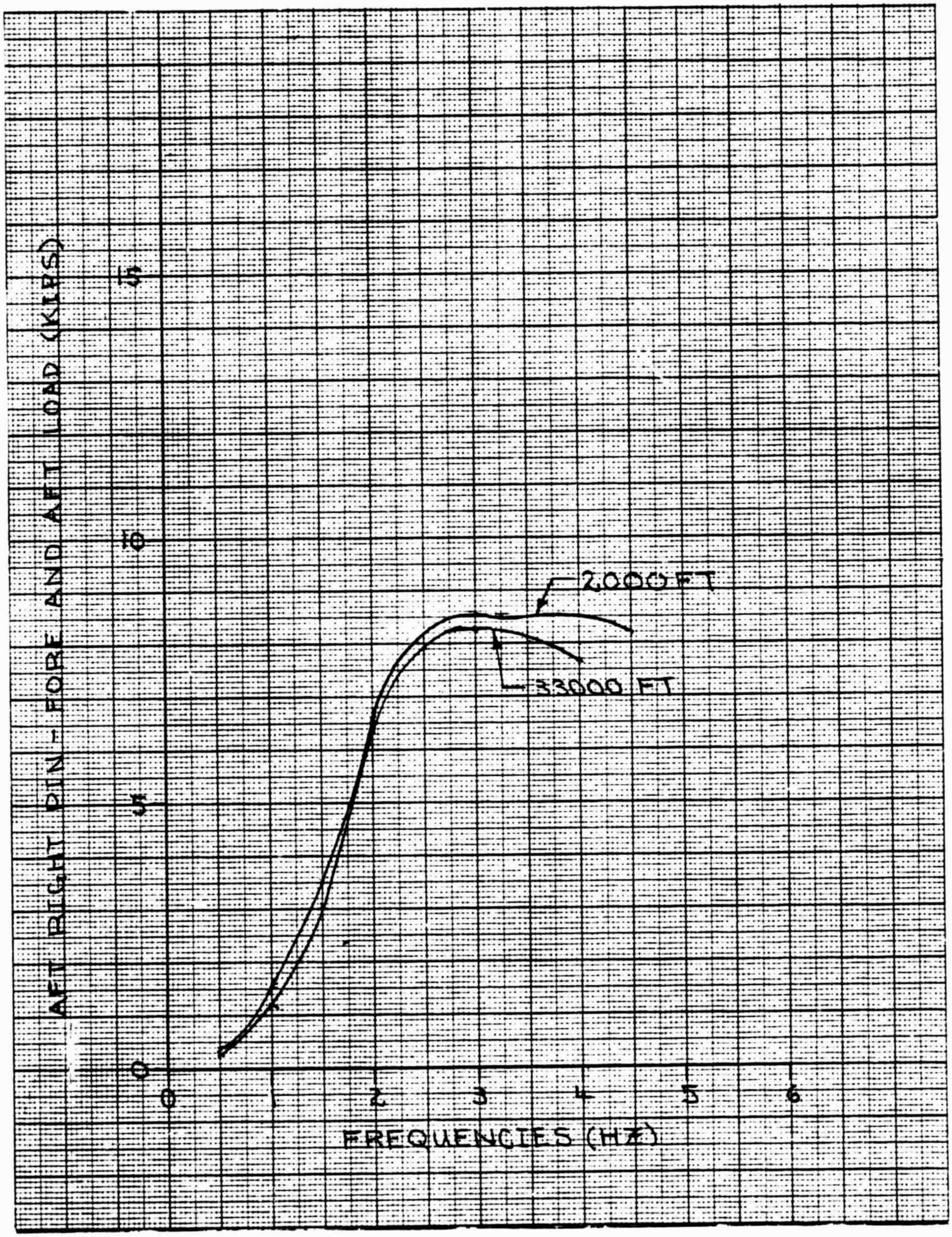

FIGURE 22

LOADS FOR ONE 25 FT/SEC GUST TRUE AIRSPEED AT THE ABOVE FREQUENCIES

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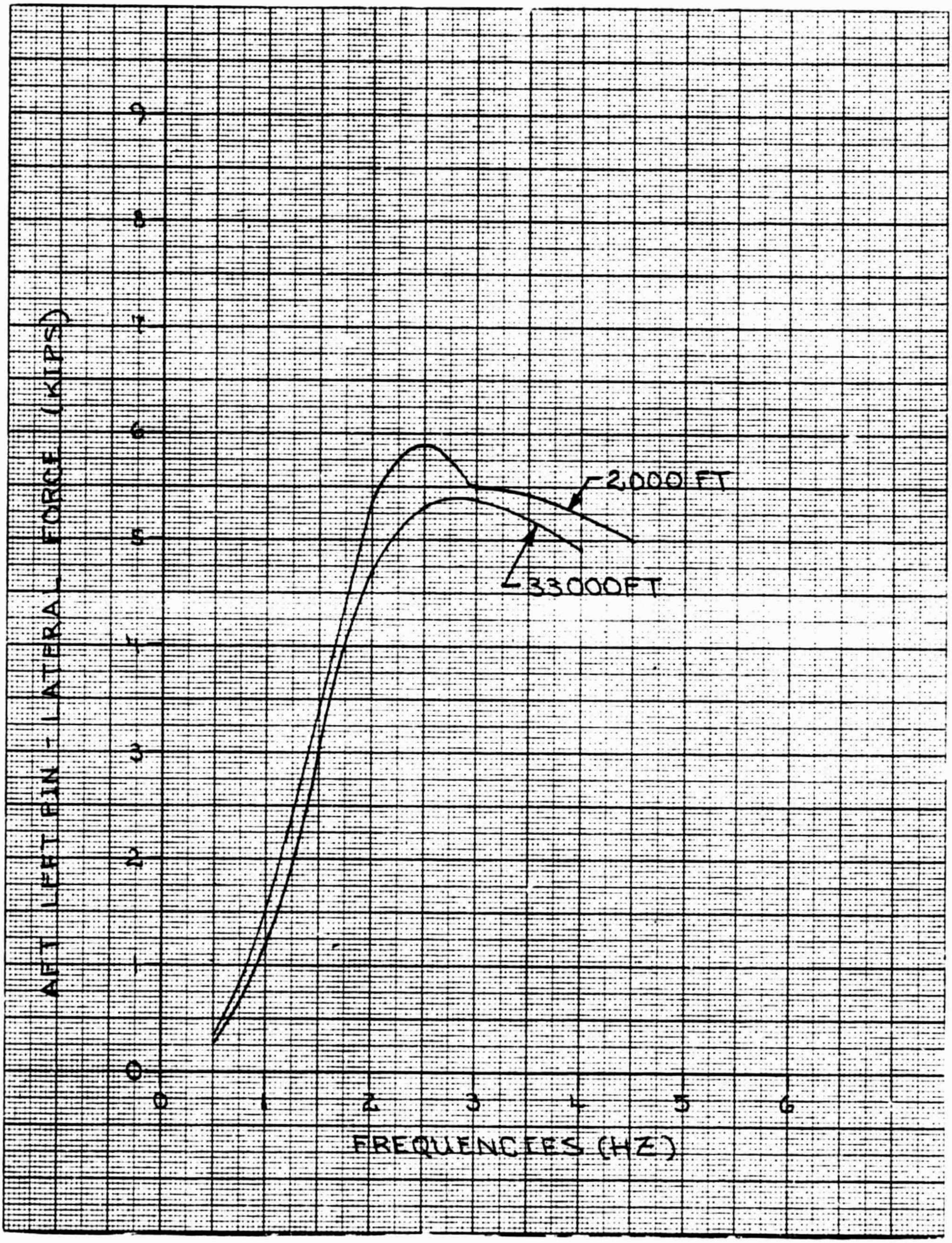

FIGURE 23

LOADS FOR ONE 25 FT/SEC GUST TRUE AIRSPEED AT THE ABOVE FREQUENCIES

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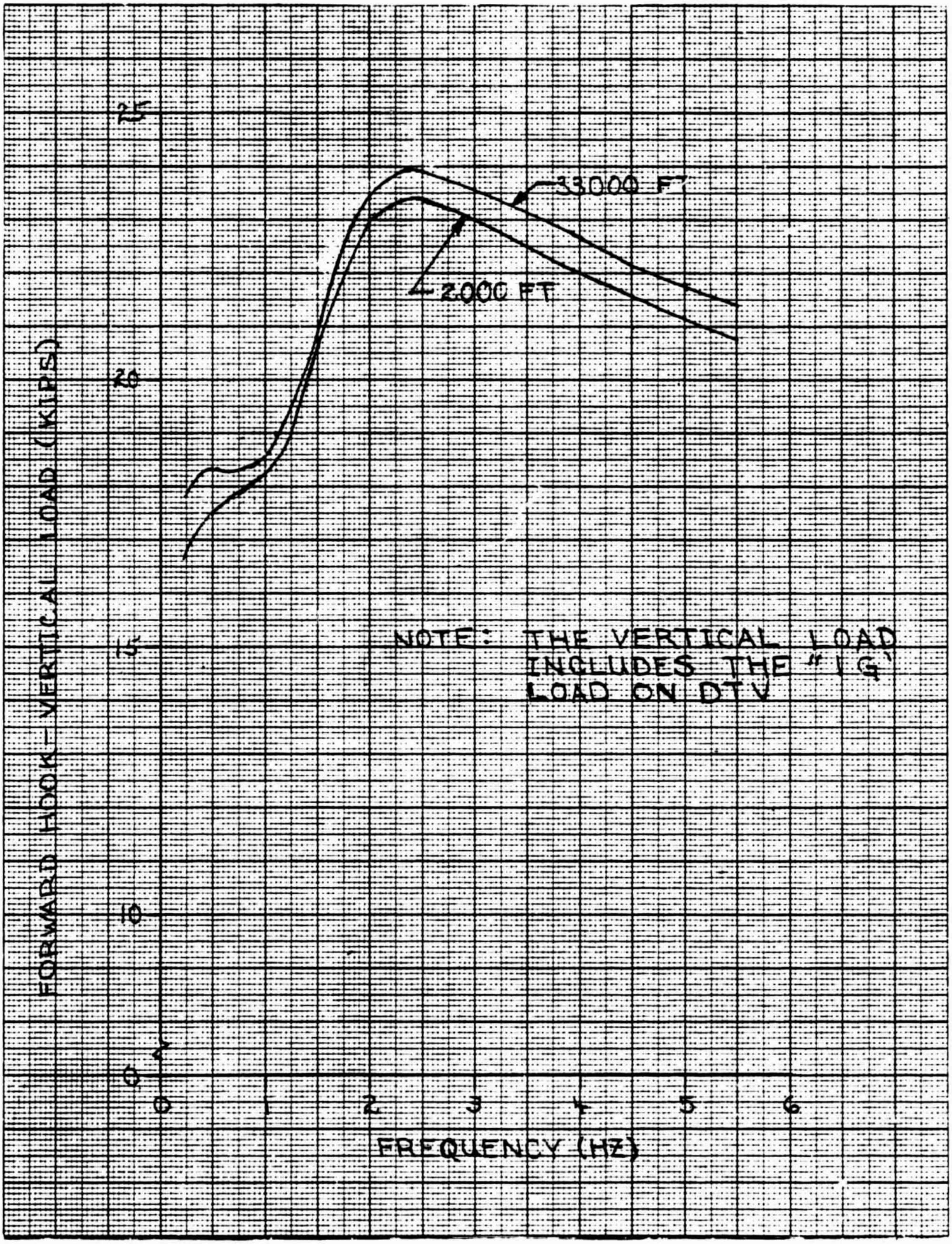

FIGURE 24
LOADS FOR ONE 4.75 DEGREE ELEVATOR DEFLECTION AT THE ABOVE FREQUENCIES

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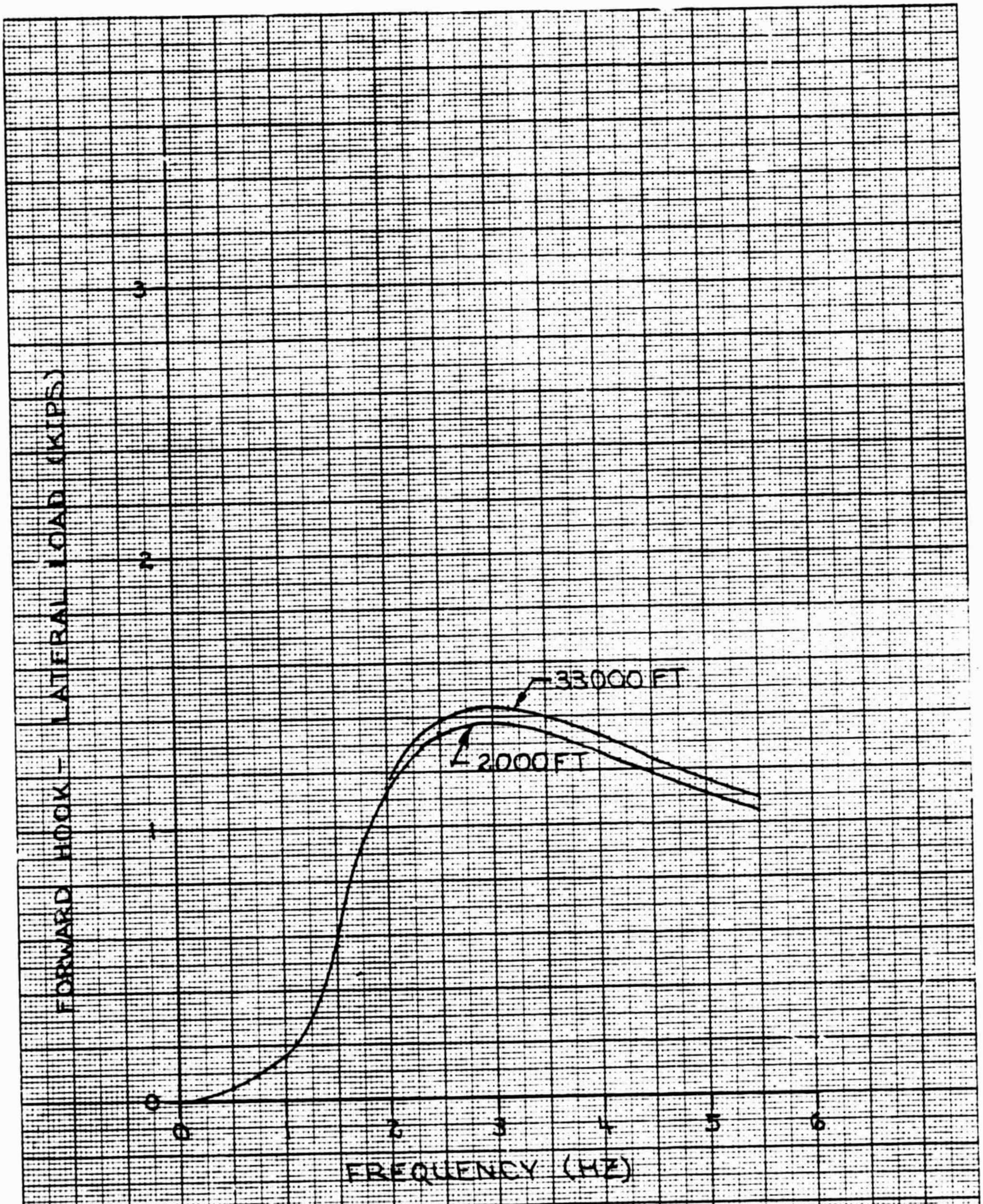

FIGURE 25
LOADS FOR ONE 4.75 DEGREE ELEVATOR DEFLECTION AT THE ABOVE FREQUENCIES
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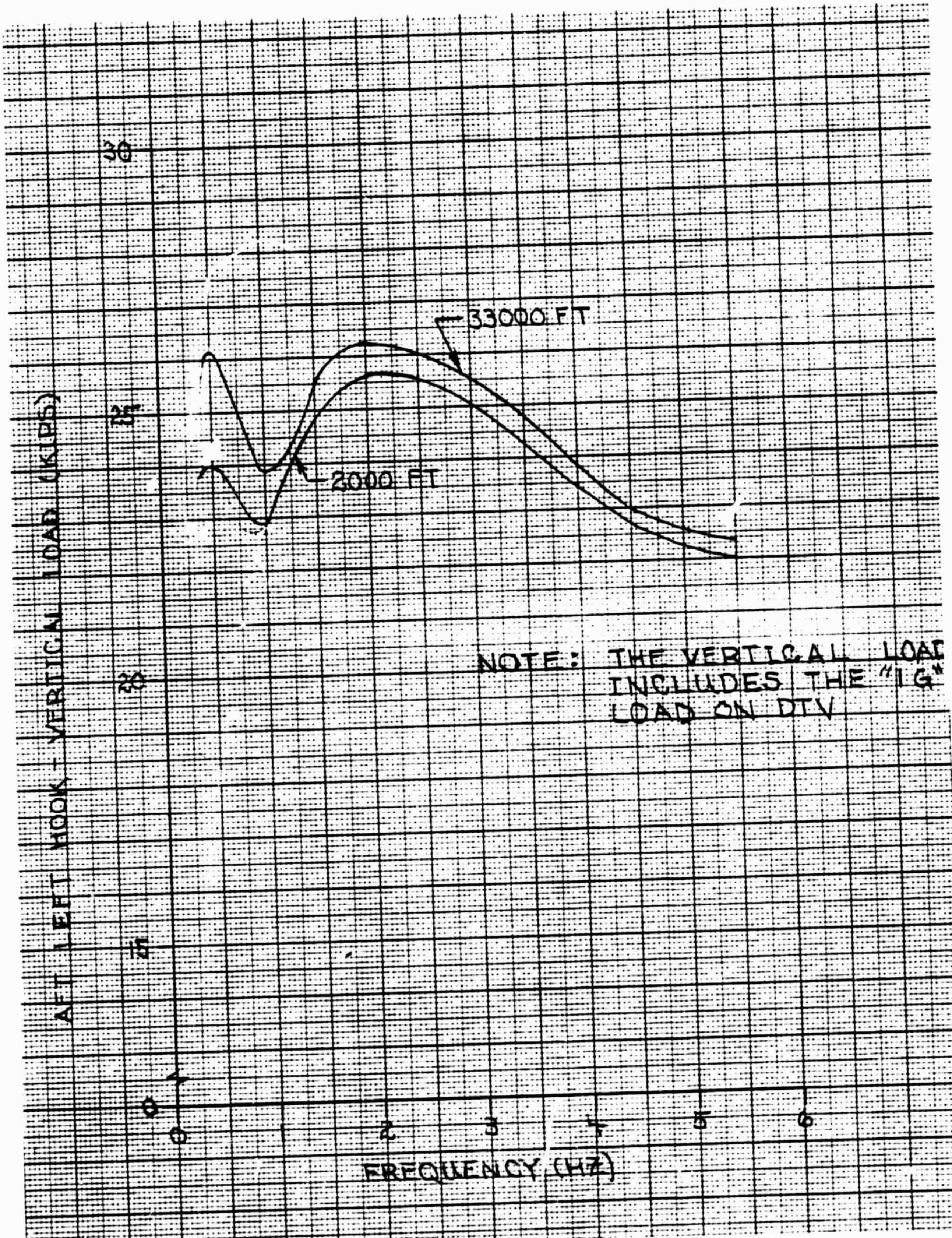

FIGURE 26

LOADS FOR ONE 4.75 DEGREE ELEVATOR DEFLECTION AT THE ABOVE FREQUENCIES

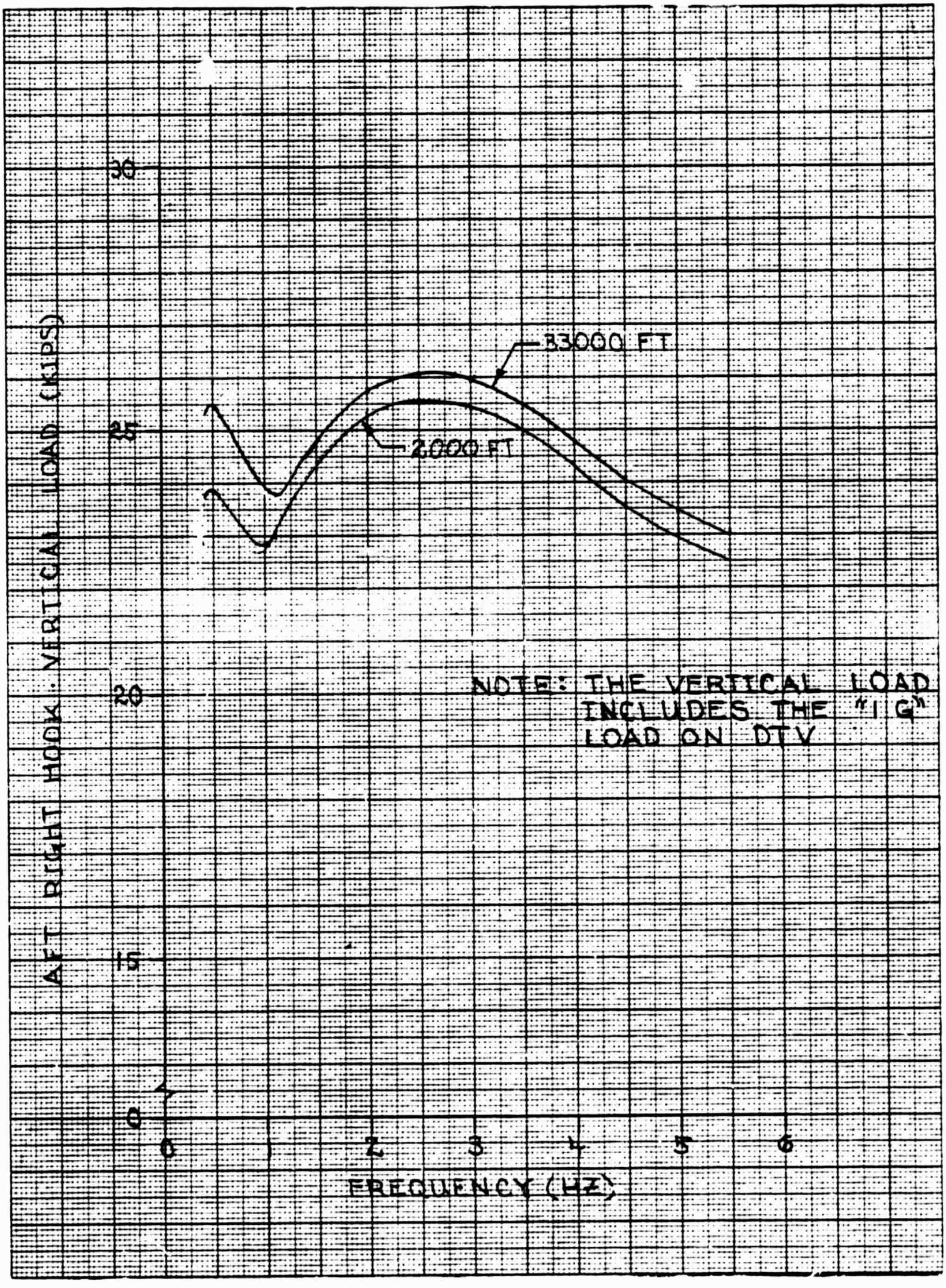

FIGURE 27

LOADS FOR ONE 4.75 DEGREE ELEVATOR DEFLECTION AT THE ABOVE FREQUENCIES

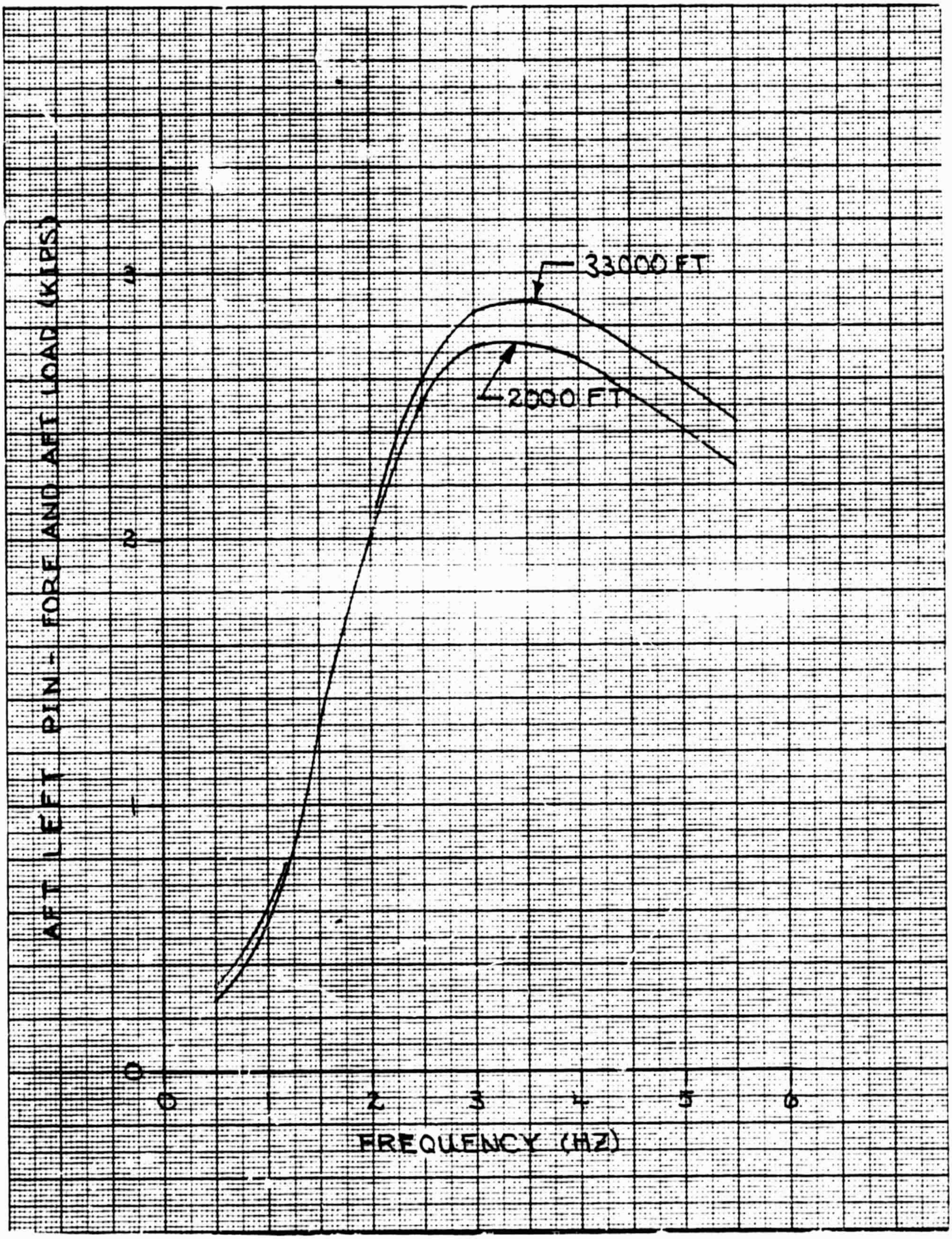

FIGURE 28
LOADS FOR ONE 4.75 DEGREE ELEVATOR DEFLECTION AT THE ABOVE FREQUENCIES

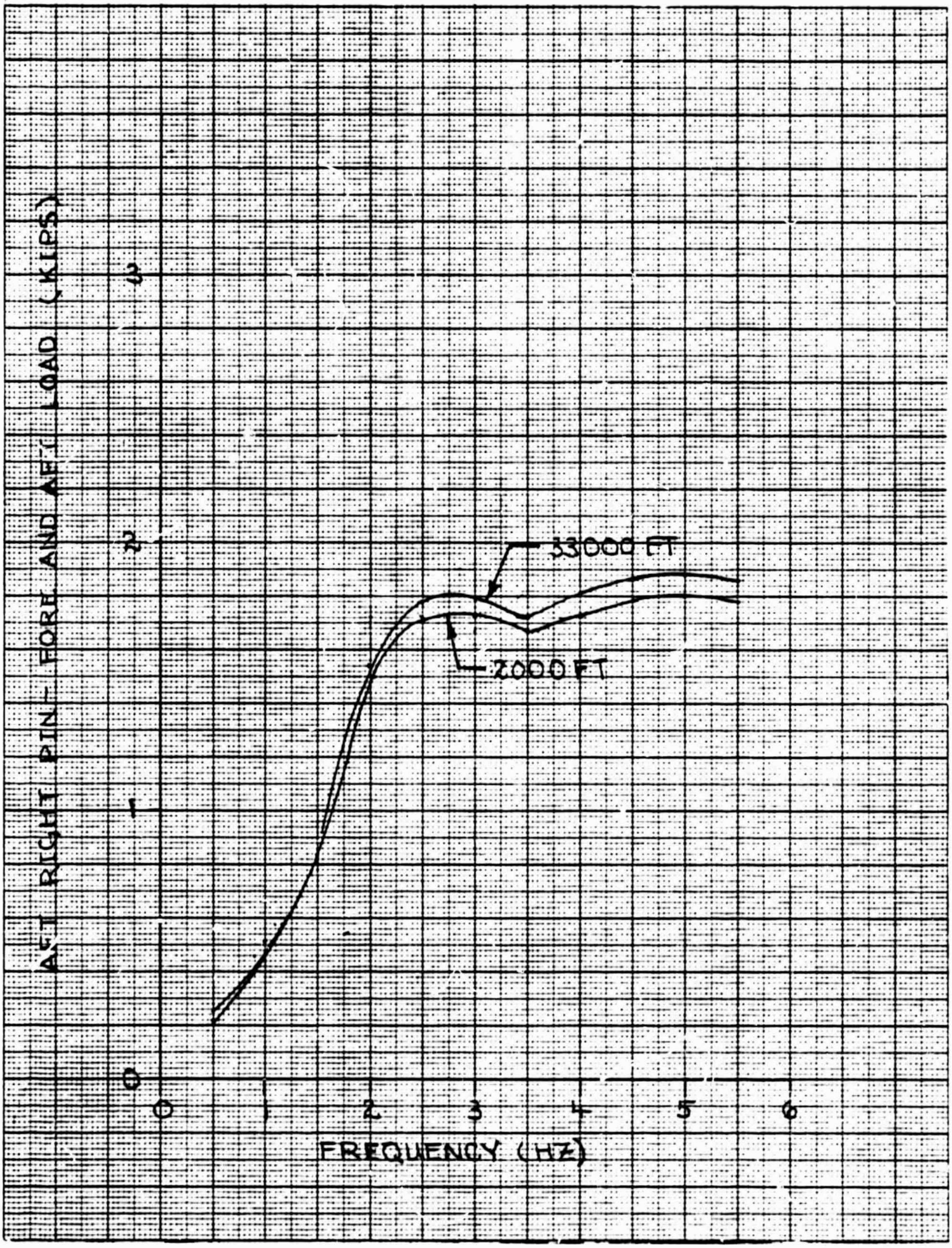

FIGURE 29
LOADS FOR ONE 4.75 DEGREE ELEVATOR DEFLECTION AT THE ABOVE FREQUENCIES
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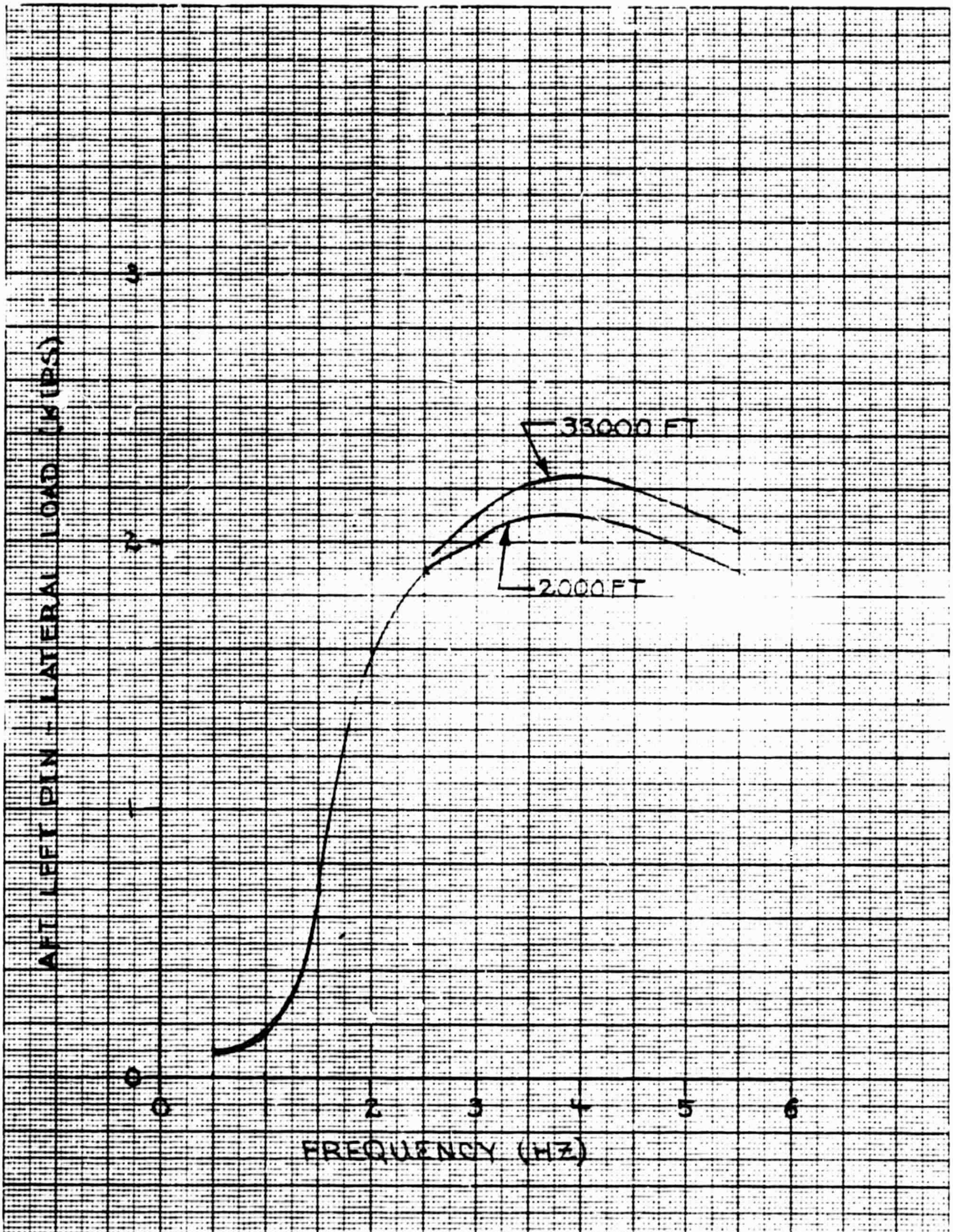

FIGURE 30

LOADS FOR ONE 4.75 DEGREE ELEVATOR DEFLECTION AT THE ABOVE FREQUENCIES

D500-10379-1

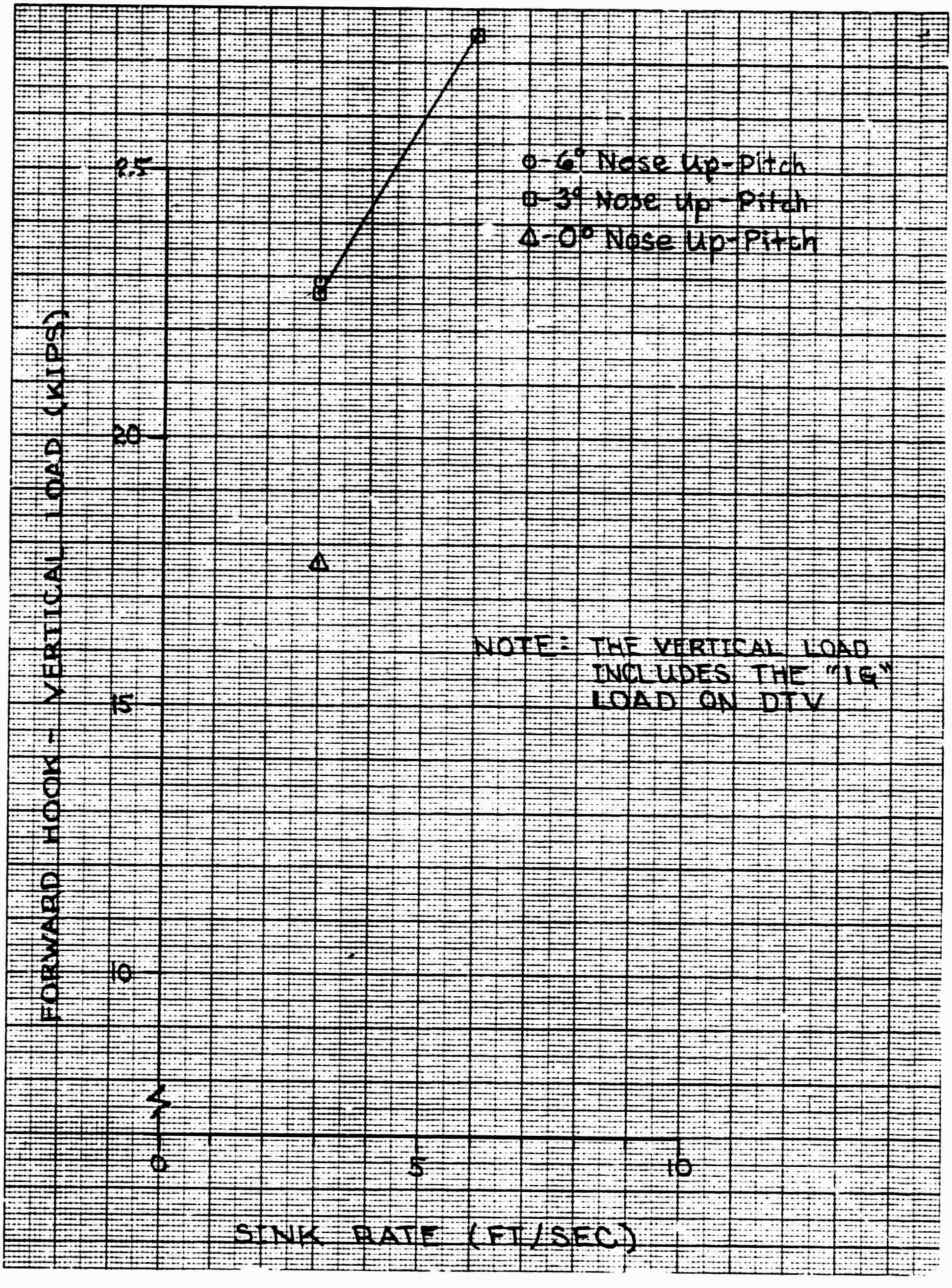

FIGURE 31
LANDING LOADS - 140 KEAS FOR 3 FPS AND 6 FPS SINK RATES

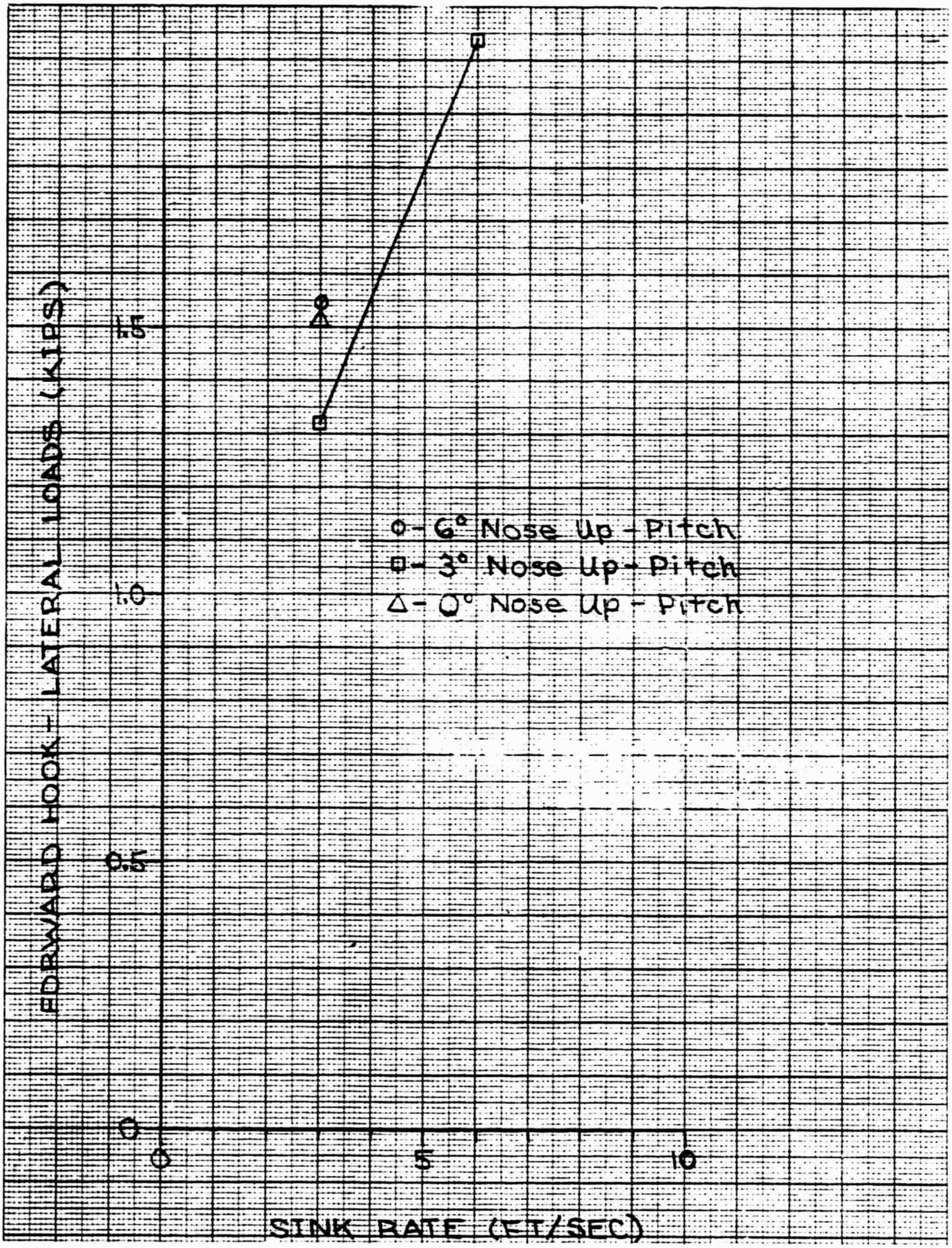

FIGURE 32

LANDING LOADS - 140 KEAS FOR 3 FPS & 6 FPS SINK RATES

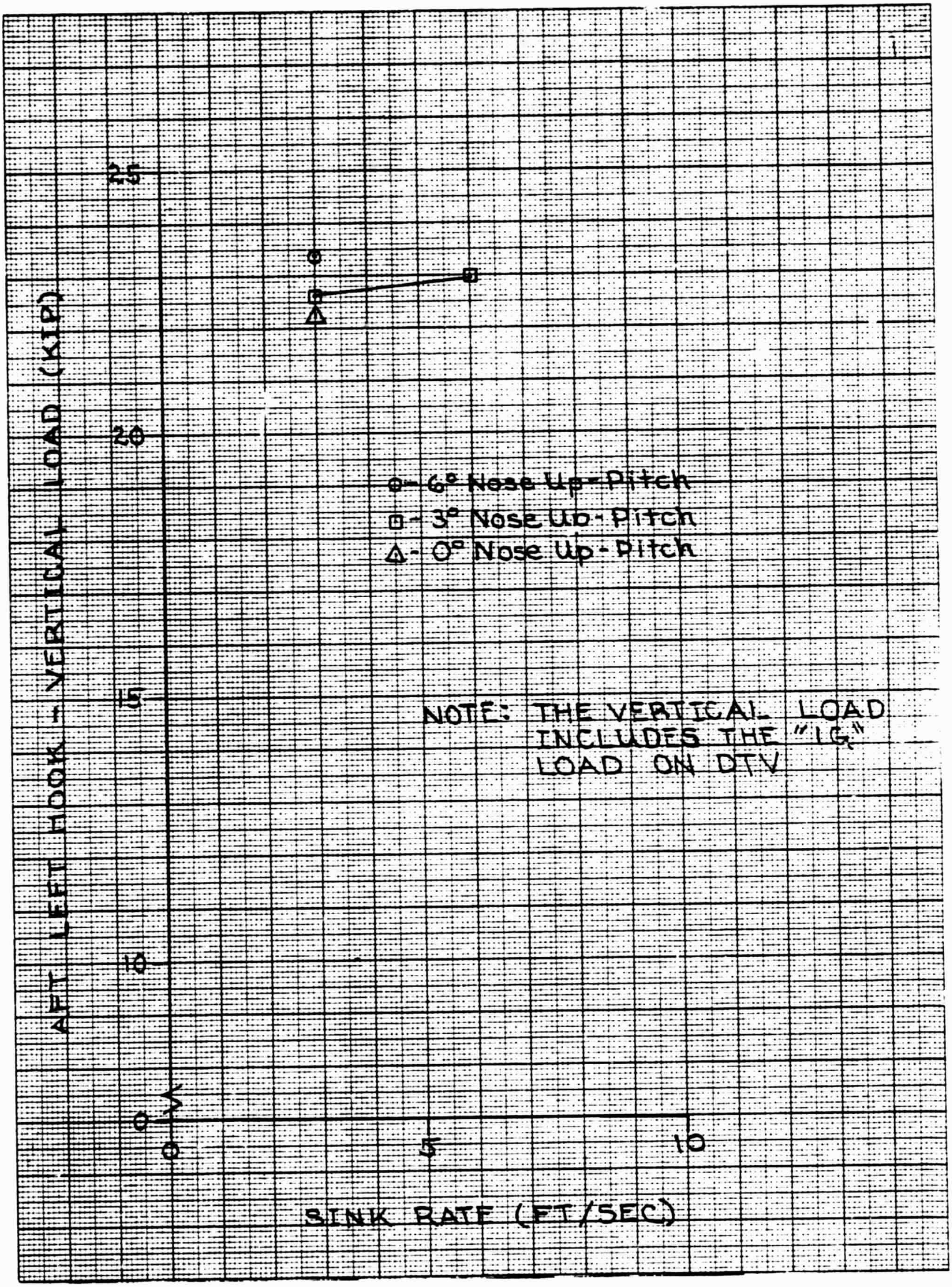

FIGURE 33

LANDING LOADS - 140 KEAS FOR 3 FPS & 6 FPS SINK RATES

D500-10379-1

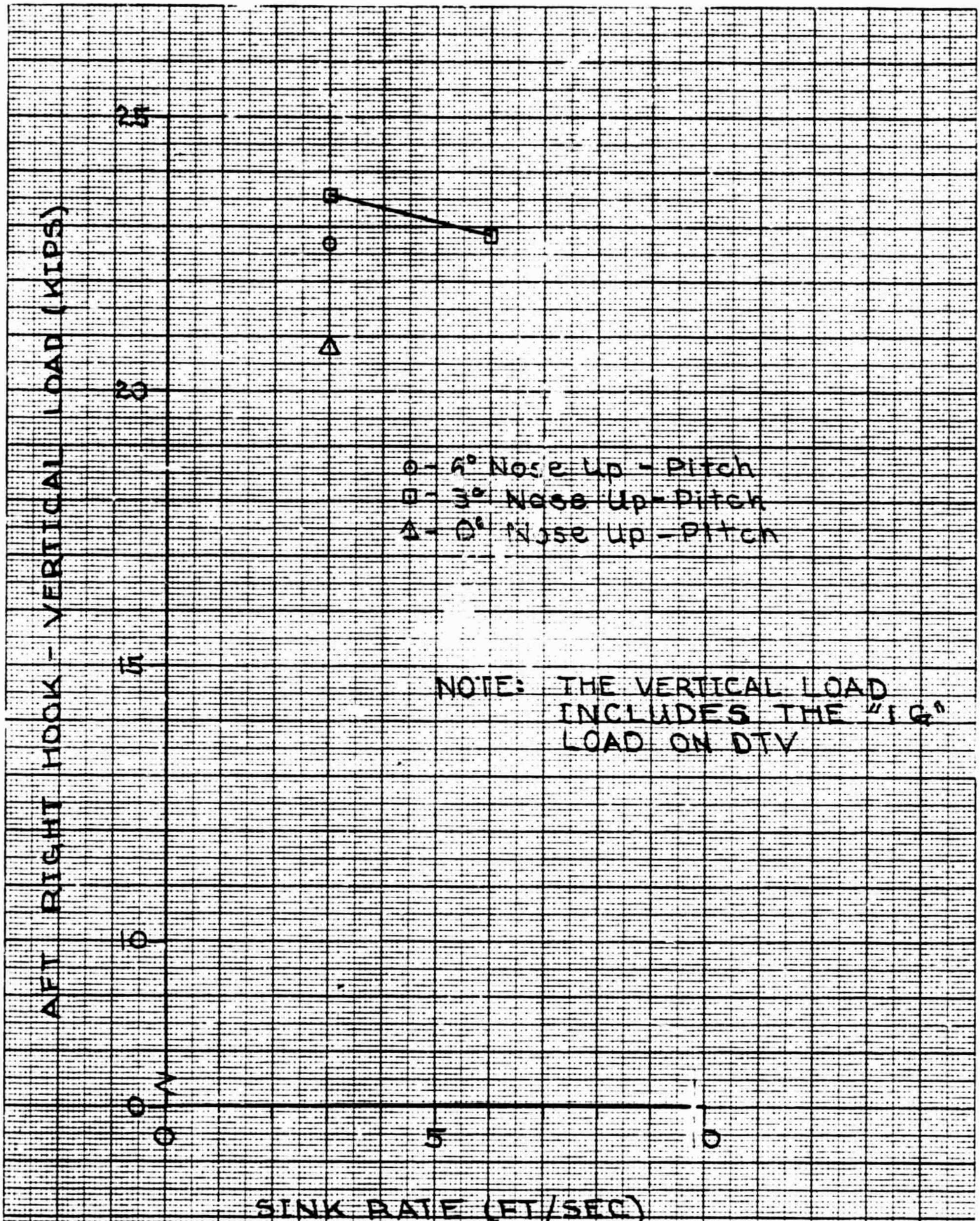

FIGURE 34

LANDING LOADS - 140 KEAS FOR 3 FPS & 6 FPS SINK RATES

D500-10379-1

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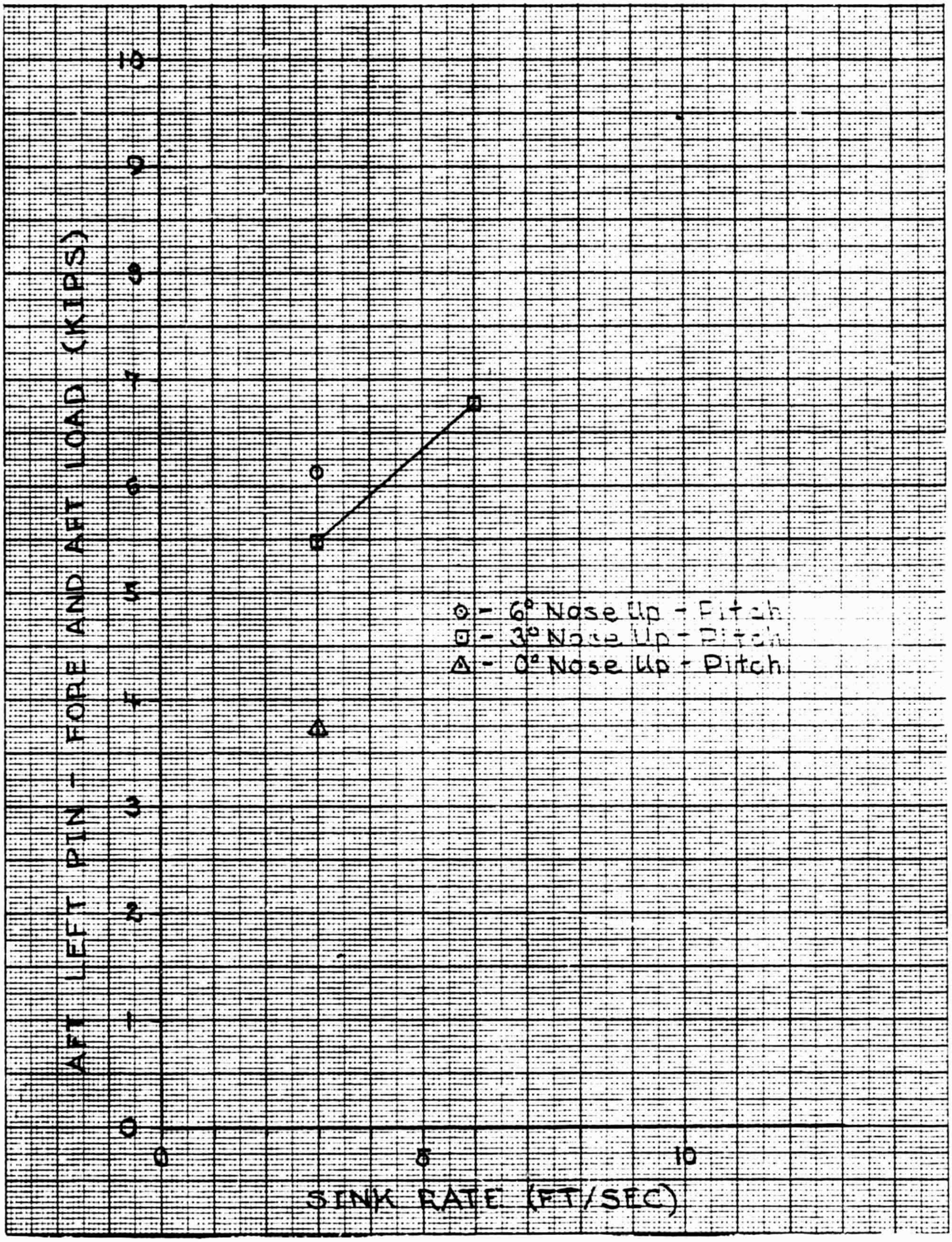

FIGURE 35
LANDING LOADS - 140 KEAS FOR 3 FPS & 6 FPS SINK RATES
D500-10379-1

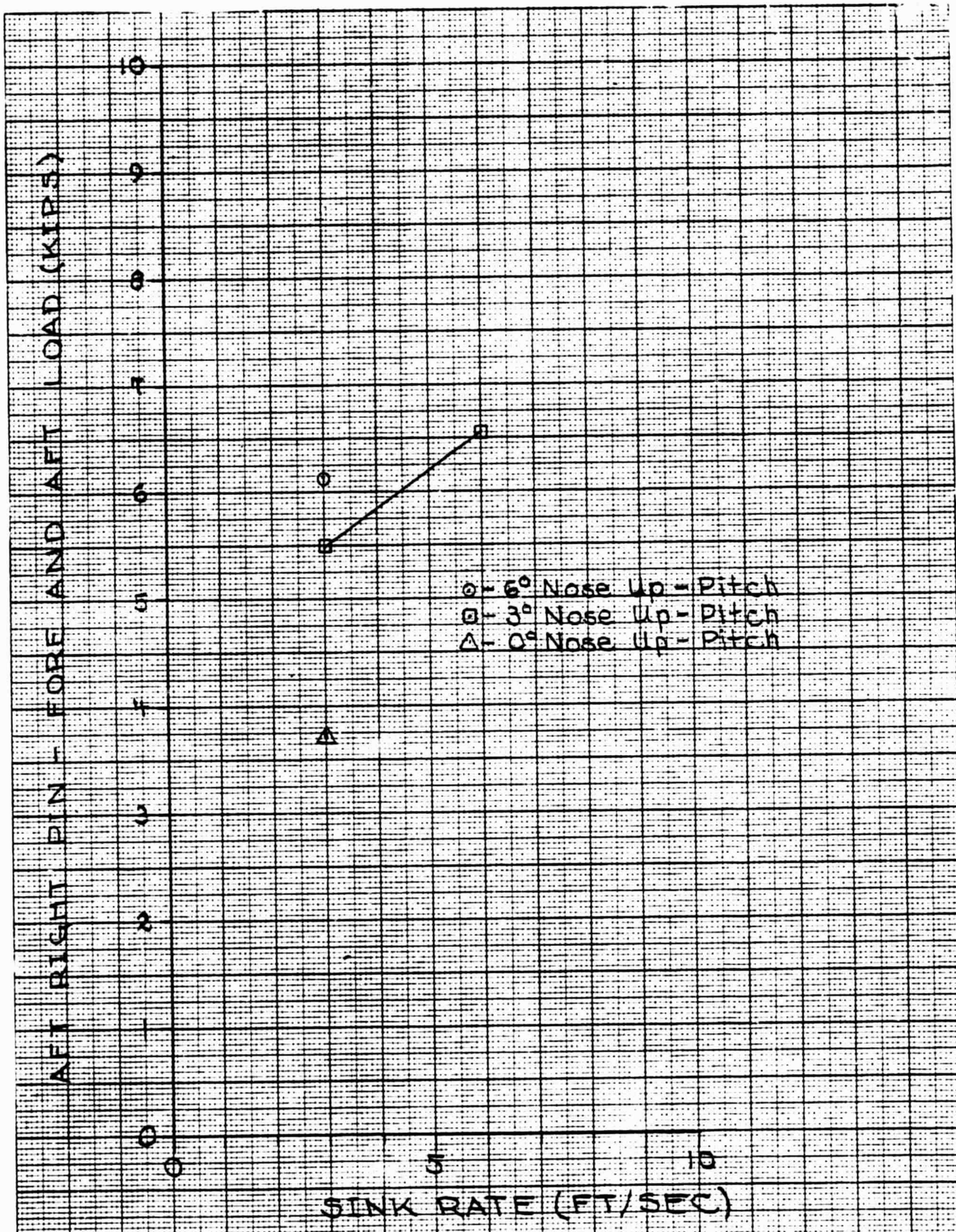

FIGURE 36
LANDING LOADS - 140 KEAS 3 FRS & 6 FPS SINK RATES
D500-10379-1

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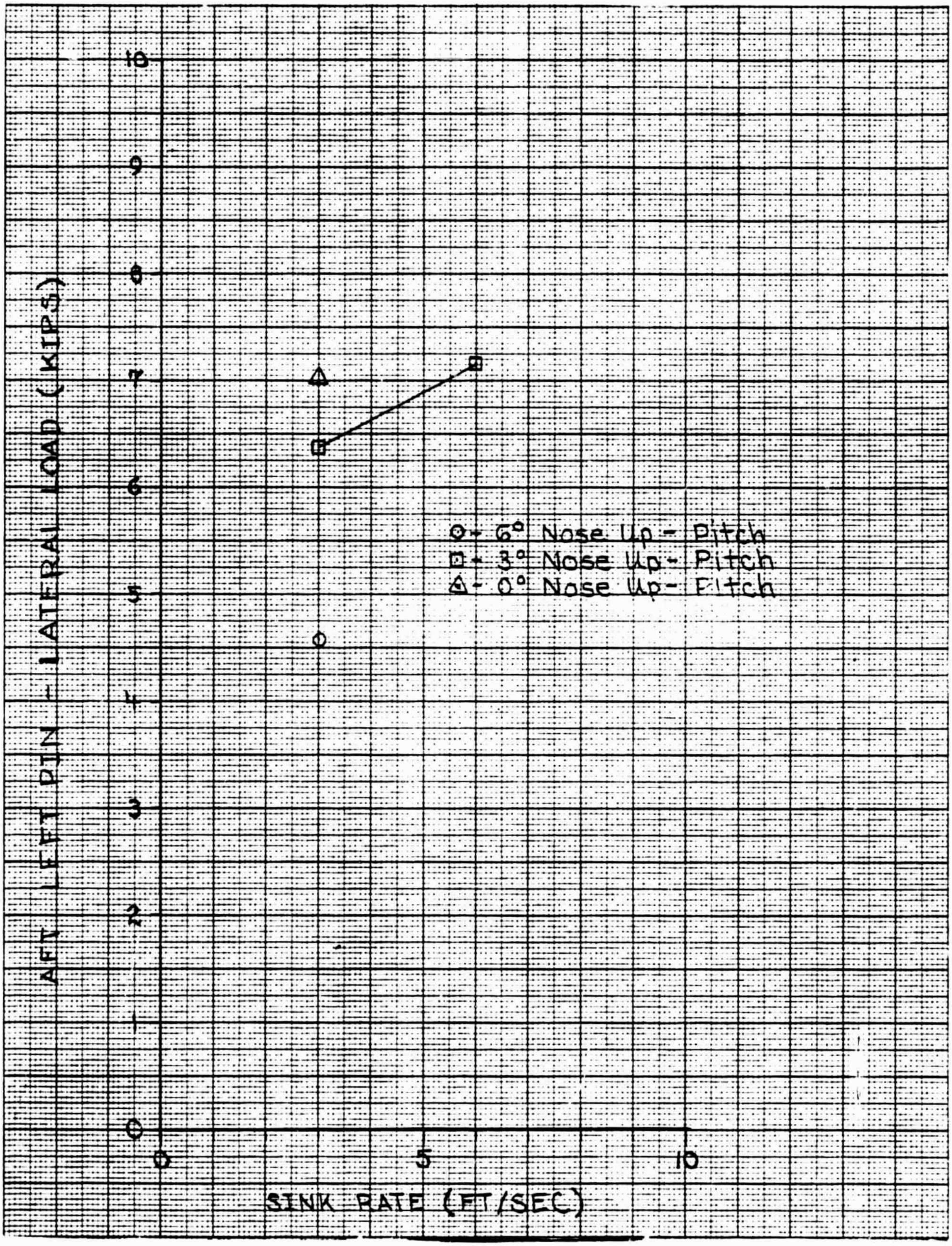

FIGURE 37
LANDING LOADS - 140 KEAS 3 FPS & 6 FPS SINK RATES
D500-10379-1

LOAD COMPONENT	X-15 ANALYSIS		1.5 MAXIMUM REVISED DROP TEST VEHICLE LOAD					
	ULTIMATE LOAD (LBS)	MARGIN	25 FT/SEC VERT. GUST (TRUE AIRSPEED) (LBS)	ELEV. INPUT ¼ MAX. DEF'L (LBS)	LANDING 6°NOSE UP 3 FPS S.R. (LBS)	LANDING 3°NOSE UP 3 FPS S.R. (LBS)	LANDING 0°NOSE UP 3 FPS S.R. (LBS)	LANDING 3°NOSE UP 6 FPS S.R. (LBS)
FWD HOOK VERTICAL	-56624	.01*	52350	35900	34370	34100	26480	41290
FWD HOOK LATERAL	13002	.27**	14400	1860	2310	1980	2280	3050
AFT LEFT HOOK VERTICAL	-86456	.06*	45600	39400	34920	33920	33340	34460
FT RIGHT HOOK VERTICAL	-78599	.17*	45750	39150	34050	35390	31220	34270
AFT LEFT PIN FORE & AFT	46702	.12*	12600	4350	6130	5490	3720	6570
AFT RIGHT PIN FORE & AFT	43705	.29*	12820	2850	4600	4790	5710	6250
AFT LEFT PIN LATERAL	-36751	.51*	8850	3380	4570	6384	7040	7160

* REFERENCE TFD 66-431

** REFERENCE TFD 63-876

FIGURE 38

RELATIVE CRITICALITY OF B-52/REVISED DTV LOADS

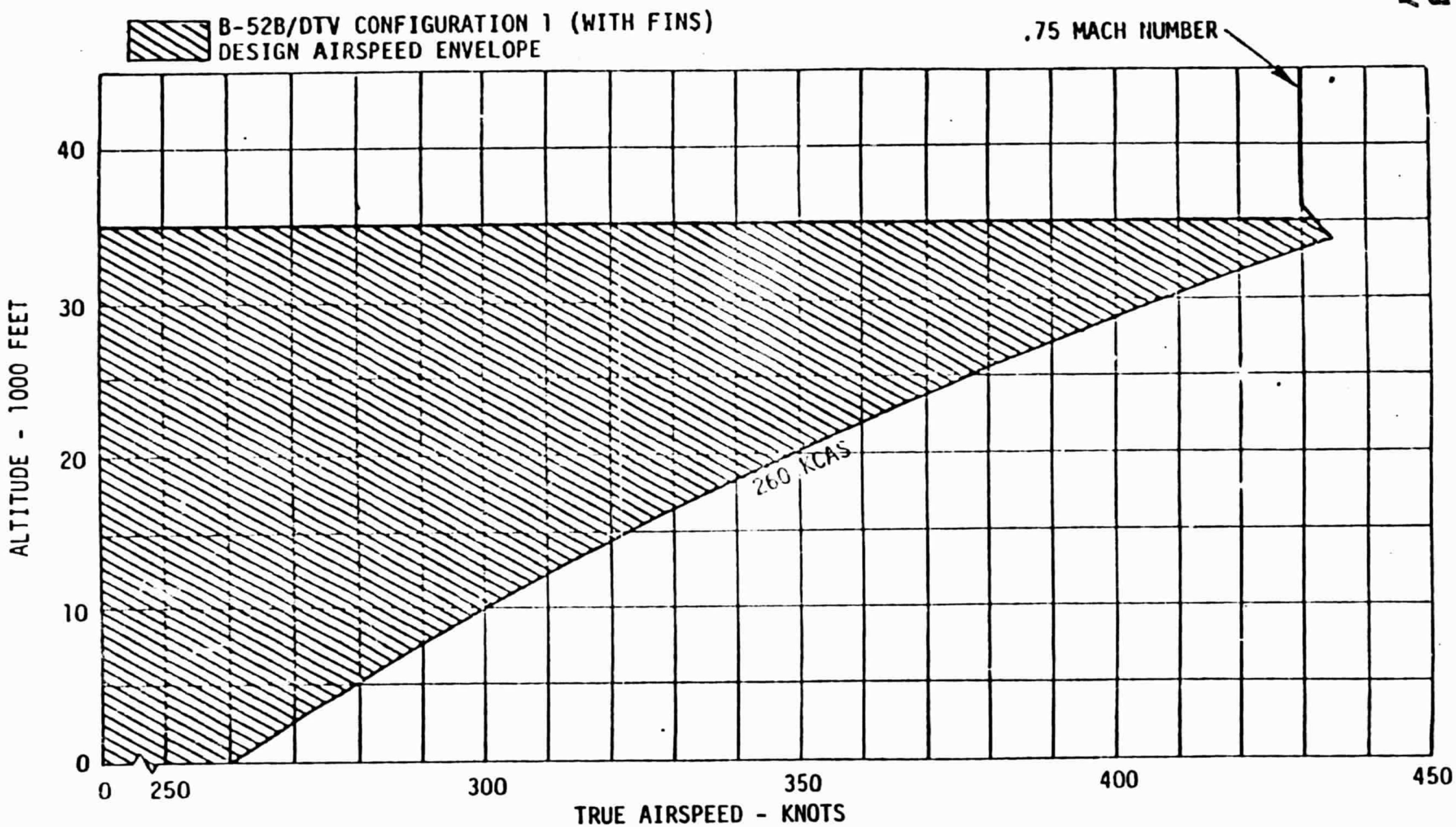

FIGURE 39

B-52B/DTV CONFIGURATION 1 (WITH FINS)
DESIGN AIRSPEED ENVELOPE

6. REFERENCES

1. Boeing Document D3-11220-2, "Load and Dynamic Assessment of B-52B-008 Carrier Aircraft for Finned Configuration 1 Space Shuttle Solid Rocket Booster Decelerator Subsystem Drop Test Vehicle-Volume I, Summary", dated 6 October 1978.

2. Boeing Document D3-11220-2, "Load and Dynamic Assessment of B-52B-008 Carrier Aircraft for Booster Decelerator Subsystem Drop Test Vehicle-Volume II, Flutter and Load Analysis Results", dated 6 October 1978.

3. Boeing Document D3-11220-2, "Load and Dynamic Assessment of B-52B-008 Carrier Aircraft for Finned Configuration 1 Space Shuttle Solid Rocket Booster Decelerator Subsystem Drop Test Vehicle - Volume III, Pylon Loading at the DTV and Wing Interface Attach Points using Stiffness Method 1," dated 6 October 1978.

4. Boeing Document D3-11220-2, "Load and Dynamic Assessment of B-52B-008 Carrier Aircraft for Rocket Booster Decelerator Subsystem Drop Test Vehicle - Volume IV, Pylon Loading at the DTV and Wing Interface Attach Point using Stiffness Method 2," dated 6 October 1978.

5. Boeing Document D3-11220-1, "Load and Dynamic Assessment of B-52B-008 Carrier Aircraft for Configuration 1 and 2 Space Shuttle Solid Rocket Booster Decelerator Subsystem Drop Test Vehicles - Volume I, Summary", dated 24 October 1977.

6. Boeing Document D3-11220-1, "Load and Dynamic Assessment of B-52B-008 Carrier Aircraft for Configuration 1 and 2 Space Shuttle Solid Rocket Booster Decelerator Subsystem Drop Test Vehicles - Volume II, Airplane Flutter and Load Analysis Results", dated 24 October 1977.

7. Boeing Document D3-11220-1, "Load and Dynamic Assessment of B-52B-008 Carrier Aircraft for Configuration 1 and 2 Space Shuttle Solid Rocket Booster Decelerator Subsystem Drop Test Vehicles - Volume III, Pylon Loading at the DTV and Wing Interface Attach Points using Stiffness Method 1", dated 24 October 1977.

8. Boeing Document D3-11220-1, "Load and Dynamic Assessment of B-52B-008 Carrier Aircraft for Configuration 1 and 2 Space Shuttle Solid Rocket Booster Decelerator Subsystem Drop Test Vehicles - Volume IV, Pylon Loading at the DTV and Wing Interface Attach Points using Stiffness Method 2", dated 24 October 1977.

6. REFERENCES (Continued)

9. No. R-1803-2B, "Basic Flight Criterion", Amendment No. 2, dated 17 June 1949.

10. Boeing Document D-10754, "External Loads Criteria, Volume III", Model B-52, dated 14 February 1951.

ACTIVE SHEET RECORD

SHEET NO.	REV LTR	ADDED SHEETS				SHEET NO.	REV LTR	ADDED SHEETS			
		SHEET NO.	REV LTR	SHEET NO.	REV LTR			SHEET NO.	REV LTR	SHEET NO.	REV LTR
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2						47					
3						48					
4						49					
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